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ADDRESS TO THE SOCIETY OF FORESTERS[1]

BY R. L. ROBINSON

ON the conclusion of its first year of existence the Society may look back with quiet satisfaction on what has been accomplished. The membership is already over one hundred, and, while not large, exceeds our first expectations. The first number of the Journal was well received by the forestry public in all parts of the world, and a number of notes of appreciation have been received from overseas and in particular from America and Australia. There has been some criticism that the Journal was not as technical in character as it might have been; but this defect, if such it be, is one which can easily be remedied. It must be our endeavour to keep the standard of publication high, and I think we may confidently look to Dr. Steven and his associates to accomplish this.

It is definitely laid down in the rules of the Society that the President on demitting office shall deliver an address, which *inter alia* shall include a review of the increase of forestry knowledge during the preceding year.

The task which has thus been set me is one which I have found difficult to perform even to my own satisfaction. Knowledge comes to us in various ways; partly by the handling of facts and situations, partly through published reports and papers. The field covered by forestry is now a very wide one, including, as it does, among other things the whole technique of growing timber and other forest products, the protection of the growing crops, and their utilization when grown. As aids to these processes we call in all the natural and most of the applied sciences. On the other hand, we are constrained in practice to work within the limits of policy, and knowledge which bears on policy, even if it has no basis in technical forestry, cannot be disregarded. Add to these the fact that forestry publications in different languages become ever more numerous and it will at once appear that any attempt to deal in a single paper with the whole range of knowledge is foredoomed to failure.

In approaching the subject I have been led in the first instance to consider the nature of forestry knowledge. So far as the technique of timber production is concerned the outstanding feature is the empirical nature of a large proportion of it. We are daily putting into practice methods which have been built up as the result of long years of experience. The best we can do is to relate broad causes with broad effects. It is not an exact science and I doubt whether we can ever in our time make it so. Our analyses of the complex natural processes which go on are necessarily imperfect, even to the point that we can never be certain that we have succeeded in enumerating the individuals comprising the complex.

Take, for example, the two parts of the forest—that above and that below ground—and reflect how often we are content to found our judgements on what we can readily see to the exclusion of the factors which are at work beyond our

[1] Delivered at the Annual Meeting of the Society held in Edinburgh on the 3rd February, 1928.

vision. This empiricism extends not only to growing timber but to its utilization, to the processes of seasoning, for example.

I assume that the most striking development of recent years in all branches of knowledge is the increased application of what are known as scientific methods. Forestry has shared in this movement. There has been a growing tendency to get knowledge on to a surer basis or data recorded on scientific (and statistical) lines. Observers are no longer content to accept general results, they seek to get at more intimate things and having got them to assess the order of accuracy of their results. There are difficulties in applying statistical methods to biological problems, and there exists the danger of pursuing the statistics rather than the problem, but there is no doubt that in scientific methods we have a powerful weapon which will accelerate progress and place forestry on a much firmer foundation.

The general process which I now imagine to be going on with regard to forestry knowledge is this: the bulk of our practice is empirical, but little by little it is being put through the sieve of experiment and research; further additions are constantly being made from both sources and gradually the valuable material is being separated from the worthless.

Again, in considering this question of the increase of knowledge one has to strive after some measure of perspective. Not everything that is hailed with satisfaction at the time of its emergence will stand the test of time and practice. If we could by some act of magic view in retrospect for our time the whole curve of true knowledge plotted to the co-ordinates x (knowledge) and y (time), I venture to think we should be surprised to find how little x had really changed in a single year. We should be far more inclined to consider our contribution as being of the order dx and to assess it not in absolute values but rather in terms of $\frac{dx}{dy}$ which in mathematical language indicates the direction or tendency in which our work was proceeding at any moment.

It is to this question of tendencies that I propose to address the remainder of my remarks.

FOREST RESOURCES.

In almost all countries there has been a steady increase in the knowledge of forest resources. We in Great Britain have recently completed a census of our woodlands and of the production (fellings) of timber for the year 1924. Most of the units of the British Empire have some progress to report.

Finland is an example of a foreign country largely forest which has made a complete inventory of its resources by regular methods of sampling.

This work is a necessary background against which to view the forestry position and questions of policy which depend therefrom.

FORESTRY TECHNIQUE.

Under this head I include the processes of growing timber (both silviculture and management). In our own case the problems relate more to the recon-

stitution of the war-felled areas and to the afforestation of uncultivated land than to the treatment of growing woods. Nevertheless, we are not altogether barren of the latter, and in the case of oak woods have made some progress in methods of securing natural regeneration. In cases where planting is necessary the tendency is to revert to the use of one-year oak seedlings spaced very closely together.

Afforestation. I think it is true to say that, as regards methods of afforestation, we have been adhering pretty closely to methods which were in vogue before the present large-scale developments were entered upon. The few years during which the Forestry Commission has been at work have brought into relief certain problems relating to nursery and planting technique which really deserve more than passing comment. We were apt in the earlier stages to assume that a common planting method was suitable for all species and that, except on the score of expense, pit-planting gave the best results. The difficulties which were experienced, however, in establishing crops of spruce have forced us to reconsider this point of view. Our reconsideration took the form of examining the roots of many thousands of spruces, and in determining conditions which inhibited growth. As a result we have come to lay more stress on shallow planting, which, to my mind, is merely an expression of the fact that the roots of spruce require more than the usual supply of oxygen, if they are to develop satisfactorily.

Closely connected with the question of spruce planting is that of the afforestation of peat areas. The laboratory work on mycorrhiza and the composition of peats, together with the extensive field-work on methods of preparing and planting peats, are yielding a steady but necessarily slow increase of knowledge. The problems involved are difficult, and it is unreasonable to expect immediate success.

As regards nursery work, we have been thoroughly overhauling current practice, attempting to ascertain in every case the reasons for different steps and the possibility of securing better results. The problem is a complex one, and we have been led into many by-paths, but gradually certain facts have emerged. It is clear, for example, that the common practice was to sow much too thickly, which resulted in large crops, it is true, but weakly individuals, and high percentage losses in transplanting. One detects symptoms of a change in outlook in our nursery procedure. Our earlier endeavour was to obtain the maximum number of plants per pound of seed, and while we have not departed wholly from that point of view, we are now inclined to be content with a more moderate number of first-class plants. The problem does not end in the nursery but must be followed into the plantation. It will take time to determine the economic objective at which to aim.

Ecology. The forester is of necessity something of an ecologist, but the detailed study which has been given in recent years to the plant associations occurring on forest soils have proved very helpful to practice. In Britain we have thus succeeded in getting a much closer insight into the problems connected with the establishment of forest crops on poor sites.

In Finland, where the natural conditions of soil and climate and exposure are constant over wide stretches of country, even greater use has been made of ecology. We understand that the Finns have succeeded in linking up what I will term the minor ecology of sites with the probable production of timber, as expressed by yield tables. We do not venture to go as far as that in this country, where the conditions are much more variable, and I am inclined to think that too much is being claimed for the procedure adopted. It seems to me that the minor flora may well turn out to be a somewhat superficial expression of site conditions, and that the trees which grow deeper and taller may find, at the one end, vastly different soil and moisture conditions, and at the other end, different exposure and transpiration conditions.

Growth Studies. There is a steady stream of knowledge issuing from our sample plot measurements year by year. These results relate, first of all, to production of timber under different conditions, and secondly, to the results of different methods of thinning. In our sample plot technique the tendency is to fell fewer sample trees and to use instead methods of volume determination based on the predetermined forms of trees.

Mycology. We have been unpleasantly reminded in the course of the year of the fact that there are exotic fungi which may prove harmful in this country. An example is the *Rabdocline* on Douglas fir and, what is possibly a greater menace, the Dutch Elm Disease which has been so destructive in Holland and other parts of Europe.

Entomology. A noteworthy incident was an outbreak of pine sawfly (*Lophyrus pini*) at Rendlesham in East Anglia and its sudden disappearance, due, it is thought, to a bacterial disease. The attack affected some 2,000 acres of young Scots and Corsican pine. I mention this case not so much because of the damage which was caused but as an illustration of how little we know of the processes which go on when insects are aggregated in great numbers. The tendency in forest entomology is now to look beyond the life-history of the insect, with which the earlier forest entomologists were more or less content, and to study the problem from a wider angle, just as in silviculture we are studying the ecology of forests.

FOREST PRODUCTS RESEARCH.

The past year has been chiefly one of preparation. The Forest Products Research Laboratory, under Mr. Pearson, has been completed at Princes Risborough and is already in partial working order. Considering the large amount of time which this necessitated in organization and in moving from the old laboratory at Farnborough, a considerable amount of useful work has been accomplished. The new laboratory makes provision for research into testing, seasoning, and preservation of timber, and is equipped with the necessary plant and wood-working machinery.

A few examples of work in progress may be of interest. From the somewhat immature Corsican pine in the New Forest sufficient material has been cut and kiln-seasoned to provide the wood-work of an experimental cottage. The

samples which we have seen indicate that this timber has a greater value than merchants have been inclined to place on it, but obviously it requires proper handling. The seasoning experiments have extended also to oak and other timber.

In association with the Forestry Commissioners, the Research Laboratory has been carrying out an extensive series of experiments on the value of home-grown pitwood. This has included mechanical tests of home-grown props, side by side with imported props, and a large-scale experiment in the mines with peeled props of different species, for example Scots pine, Corsican pine, Douglas fir, Japanese larch, oak, &c. In all cases the home-grown material has come well out of the test. The experiments are not yet at an end, but it is confidently hoped that valuable results will be secured.

The Forest Products Laboratory programme also includes a series of investigations into the protection of timber from insects and fungi and various other lines of work to which detailed reference will no doubt appear in future numbers of the Journal.

Conclusion. It will be apparent, even from the inadequate sketch that I have given, that to whatever the contemporary contribution may amount, there is considerable activity in searching for knowledge. There is a great deal of material awaiting publication, and I trust that some of it will find its way into the Society's Journal.

HARDWOODS

BY R. S. PEARSON, C.I.E.

Director, Forest Products Research Laboratory Department of Scientific and Industrial Research

THE fear that the supply of softwoods may one day run short brings forward the question whether hardwoods could in some measure take their place. When considering such a possibility the mind naturally travels to tropical hardwoods more than to the European varieties, of which the supply is relatively limited and the present prices in many cases prohibitive. If we consider the position of affairs in England as it was, say one hundred or more years ago, we find that a large proportion of the timber used in construction, especially for beams and rafters, was of hardwoods. At the present time only in exceptional cases are hardwoods used; and softwoods have taken their place, except for decorative work or buildings of a superior class. This is the case not only in England but to a greater or less extent in all countries where softwoods are available at a reasonable cost. In semi-tropical and tropical countries where hardwoods are available in quantity, such as in many of our central and western colonies of Africa, in India, Australia, the Federated Malay States, Ceylon, and others, the local hardwoods are by far the most common timbers used in house construction, for sleepers, harbour work, and many other purposes. Taking into consideration the fact that hardwoods were used in the past for construction in the British Isles and at the present time are so used in many countries, it is not unreasonable so suppose that were a serious shortage of softwoods to occur in the future, and provided that both temperate zone and tropical hardwoods were available, they might again come into common use in Europe.

Let us consider for a moment the reason why hardwoods fell into disuse for house construction. The reasons are not far to seek. Generally hardwoods are considerably heavier than coniferous woods, they are also less easy to work, often they are not available in quantity in uniform grades, while, owing to the fact that they are used for many purposes other than for construction, prices are prohibitive. In their favour is the fact that they are often very durable and of great strength.

It follows, therefore, that the determining factor is partly an economic one and partly based on the physical qualities of the timber. For example, oak was formerly in common use for construction as beams, rafters, and flooring boards. From an economic point of view, owing to its price being more than twice that of a good grade of Scots pine, its present use for construction is limited to the more expensive class of houses and then primarily for decorative purposes. Turning to its physical qualities we find that it is far heavier than pinewood, more difficult to work, though undoubtedly of greater strength

and durability. Beech, elm, sweet chestnut, and sycamore were formerly also used for construction but now only in exceptional cases, while ash was never in common use for construction as it always stood in a class of its own for special purposes. Teak may be taken as another example of a well-known hardwood used in Europe for special purposes, primarily in shipbuilding. Were it cheap in England it would probably be in common use in construction, as though considerably heavier than Scots pine it is easy to work, of uniform straight grain, and free from knots. In India and especially in Burma, where softwoods are scarce, it is the first construction wood of the country. It will be gathered from what has been said and from the two examples given that the question of using hardwoods for general building purposes, though at present generally not an economic problem in the British Isles, might possibly again be so were a serious shortage of softwoods to come about with a corresponding stiffening in prices.

Let us turn to a different aspect of the case, i.e. that of ways and means of utilizing hardwoods to greater advantage and their possible substitution for softwoods. The means of doing so that come to mind are: to reduce the sizes now in use in proportion to the superiority of the hardwoods in strength, thus reducing weight and cost and so bringing them into line with softwoods; the use of hardwoods of greater durability than that of softwoods now in use; improved methods of seasoning certain hardwoods; the use of hardwood plyboards to replace softwood matchboard and panelling; the development of built-up members of hardwoods and more intensive uses of hardwoods for special purposes.

Taking the first suggestion into consideration let us glance at the following table of strengths of some well-known soft- and hardwoods in terms of a Scots pine 9 ins. by 3 ins. joist:

Species.	*Weight per cub. ft., air dry, at about 14 per cent. moisture content.*	*Safe working stress.*[1]	*Strength per unit weight as percentage of Scots pine.*	*Depth of joist. Inches.*	*Width of joists of equal strength. Inches.*	*Weight of each 15-foot joist, in lb.*[2]
Scots pine, home-grown	38	1,420	100	9	3·0	107
Spruce	28	1,140	109	9	3·73	98
Douglas fir, Canadian	33	1,600	130	9	2·66	83
Oak, home-grown	48	1,600	89	9	2·66	120
Yellow birch, Canadian	44	1,780	108	9	2·39	99
Teak, Burma	40	1,830	122	9	2·33	88

[1] First-grade structural.

[2] Weights taken to the nearest lb.

From these figures it will be seen that a considerable saving in width is permissible in all three of the hardwoods, while in the case of yellow birch and teak the weight of a correspondingly strong joist is actually less than that of one of Scots pine, while the oak joist is not appreciably heavier. Based on the figures given in the preceding table, let us assume that we have a floor supported by Scots pine joists 9 inches by 3 inches and 15 feet long, 24 inches between centres, and let us compare it with similar floors having joists of appropriate dimensions of each of the other species—the depth of the joists remaining 9 inches. We should then have floors of the same size and strength, the only variable being the width of the joists. The width to the nearest $\frac{1}{8}$-inch would be as follows :

Species.	*Inches.*	*Volume of joist, in cub. ft.*	*Weight in lb., per joist.*
Scots pine . .	3	2·81	107
Spruce . . .	$3\frac{3}{4}$	3·51	98
Douglas fir . .	$2\frac{5}{8}$	2·46	81
Oak . . .	$2\frac{5}{8}$	2·46	118
Yellow birch . .	$2\frac{3}{8}$	2·23	98
Teak . . .	$2\frac{3}{8}$	2·23	89

Let us now consider the second suggestion, namely that by using more durable timbers an ultimate saving may be made. To produce definite figures of the relative durability of the different species of timber is not possible, especially when used under cover; on the other hand, it is a well-known fact that oak and teak are considerably more durable than Scots pine. The next possible means of using hardwood to greater advantage is to develop better methods of seasoning certain species such as elm, sycamore, and hornbeam. Elm, which is a timber of fair strength and good appearance but of very curly grain, is very liable to warp during seasoning, so much so that its use is confined to wheelwright work, parts of cars and barrows, certain colliery work, coffins, seats of chairs, and a number of special uses generally in small dimensions. Were it possible to season this fine timber and eliminate its tendency to warp, it might find extended uses. The same remarks apply to sycamore and to a more limited extent to hornbeam.

The use of ply-boards has now come into general use in England, but even more so in America and Canada. Wood built up in this way has many advantages, the most important of which are strength, lightness, appearance, and the possibility of obtaining boards of large size. Certain difficulties such as contraction and expansion in timber can also to some extent be overcome by this method of construction. Throughout this article the writer has had in mind not only the greater use of home-grown hardwoods and their possible substitution in certain instances for softwoods but that of tropical hardwoods, of which large supplies are available in certain continents. In this connexion it may be of interest to note that many of even the hardest tropical hardwoods can be cut on a rotary cutter, and made up into ply-boards, though those

with broadly interlocked grain do not lend themselves to peeling into thin veneers. It should also be pointed out that Nature has adopted in certain cases a modified form of ply to strengthen the stem of trees by the regular arrangement of interlocked bands of fibre, such as are found, for instance, in the *Pterocarps* or padauks. The use of ply-wood in construction deserves encouragement, especially that made of hardwoods. How far the industry in built-up members made of relatively small sections of hardwoods might be developed is difficult to estimate; it is, however, a possible line for research and one that requires attention.

The question of more intense utilization of hardwoods is one for research, the application of research results, and intense marketing. One instance has already been cited, namely that of elm, which, were it possible to season it satisfactorily, would undoubtedly find extended markets. The question of research applies with even more force when considering the majority of tropical hardwoods about which little information is available as to their qualities and how to handle them, and which might be profitably utilized to greater advantage in order to conserve the ever-diminishing supply of softwoods.

When considering which species of hardwood might be most profitably used as substitute for softwoods in construction, as the latter become scarcer and more expensive, or which it might be profitable to cultivate, one not unnaturally turns to oak, which is the strongest and most durable species available in the British Isles. On the other hand, foresters will more likely look for a faster-grown timber to plant, and were they to select black Italian poplar they would have chosen a useful species, suitable for ply-work, boarding, boxes, and a number of special articles. Plane, sycamore, wych elm, and sweet chestnut would also have to be considered, because if properly seasoned they are sound timbers. Turning to timbers of Empire origin, a large number might be mentioned, but of those of outstanding merit and of which supplies are very considerable may be mentioned yellow birch, *Betula lutea*, Mic., and maple, *Acer saccharum*, Marsh., from Canada; jarrah, *Eucalyptus marginata*, Sm., karri, and *E. diversicolor*, F.M., of Australia; Tasmanian oak, *E. delegaiensis*, R.T.B., and Tasmanian myrtle, *Fagus Cunninghamii*, Hook, from Tasmania; eng, *Dipterocarpus tuberculatus*, Roxb., and gurgan, *D. turbinatus*, Gaertn., of Burma and the Andamans; padauk, *Pterocarpus dalbergioides*, from the Andamans, Roxb.; iroko, *Chlorophora excelsa*, Benth. and Hook, arere, *Triplochiton nigericum*, Spr., or *T. Johnsonii*, H. Wgt., and opepe, *Sarcocephalus exulentus*, Afzet, of Nigeria and the Gold Coast; mora, *Dimorphandra Mora*, Benth. and Hook, of British Guiana; sapodilla, *Achras zapota*, L., from British Honduras; and Borneo cedar, *Shorea* spp., from British North Borneo.

SOME PROBLEMS OF FOREST SOILS

BY C. G. T. MORISON AND G. R. CLARKE

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THE study of soil in its relation to agriculture is one which is of reasonable antiquity and which has achieved certain notable successes, so much so that the modern period in agricultural research may be said to have begun with a proper understanding of the relations of soil and plant. The due control of the soil is one of the constant needs of the cultivator if he is to achieve success, and the complexity of the problem of control is such that he will be in continual need of the assistance of scientific research until it is completely solved. In some directions scientific research has achieved results which it is as yet difficult or impossible for the farmer to use, while in others knowledge has not progressed far beyond that which inspired the empirical methods of many centuries ago. In this country the pioneer work of Lawes and Gilbert at Rothamsted, and at the present time the labours of many investigators at universities and agricultural colleges, have achieved much, but most of their work has been confined to agriculture and agricultural conditions.

On the continent of Europe, in Germany and Scandinavia especially, forest soil has received more attention, but in this country little or nothing has been attempted. One of the causes which has contributed to this state of affairs is the continued neglect of forestry in this country until a few years ago, and it is hoped that the growing interest in the subject will lead to an extended study of one of its most important aspects.

Another factor which has contributed to the neglect of soil study even among foresters is the widespread opinion of many of the authoritative writers of the past that the soil was of minor importance. The forest crop, compared with the agricultural crop, demands for its annual increment little from the soil except anchorage and moisture; and it has frequently been assumed that if these are satisfactory all is well with both crop and soil. Much of this calls for re-examination in the light of modern work, and the present article is an attempt to indicate the direction in which work may profitably be undertaken in the light of recent research.

In recent years there has arisen in eastern Europe a new school of soil workers who have disregarded the relation between crop and soil, and who have sought to investigate the problems of soil as they would those of any other natural phenomenon, unfettered by the application of their knowledge to practical problems of forestry and agriculture. This method of attack has certain obvious advantages, perhaps the most important being that of simplification; but at the same time it may be doubted whether it is really possible to separate two objects so intimately connected as the soil and the growing plant. This doubt is intensified when the soil is undisturbed and is carrying

its natural flora. One of the most important directions in which the work of the Russian scientists has been successful is in devising a natural basis for the classification of soils. This resulted from a study of what have come to be known as soil profiles, vertical exposures of sections of soil down to the unaltered parent rock. Examination of these showed that they might belong to one of two great groups, those in which climate and other environmental factors had produced a definite horizon differentiation, and those in which nothing of this kind had yet occurred. The first class appear thus as *mature* soils in which pedogenic processes have had full scope, and the second as *immature*, in which they have not yet succeeded in producing their characteristic effect. The most important and striking difference between these two larger classes consists in the fact that while in the immature soils much of the soil character depends upon the parent rock from which it has been derived, maturity seems to obliterate differences in the original material, and to produce from rocks having little resemblance to each other soils sufficiently similar to be placed in the same group.

The main types of mature soils appear to be associated with the principal climatic zones of the earth's surface which may be described as

Arid, in which surface evaporation tends to exceed rainfall;
Cool Humid, in which surface evaporation is exceeded by rainfall;
Moist Tropical, in which high seasonal rainfall occurs with rapid percolation of water.

Under arid conditions the soil tends to become saline and sometimes definitely alkaline with the formation of free sodium carbonate. This production of saline substances is due to the weathering of rock into soluble salts which, owing to the limited water supply, cannot be leached quickly enough. Such soils occur in parts of the United States of America. Under semi-arid conditions where a wet season occurs followed by drought, a soil type is produced which supports a heavy growth of vegetation which does not rapidly decompose but accumulates to form the rich *black soils* of parts of Russia. Under cool humid conditions a soil type is produced on which many timber trees flourish and regenerate. The important characteristics of this group of soils are a comparatively slow decomposition of the residual organic matter in the surface horizon, a marked excess of percolation over evaporation, and a consequent leaching of soluble substances and exchangeable bases from the horizons immediately succeeding. This is slowly succeeded by the migration of humus and the sesquioxides from the same regions. This type of soil is known as the *podsol* or ash soil, from the ash-like appearance of the leached horizon. Subsequent to the leaching of the humus and exchangeable bases, a deposition of these substances occurs at a lower level, forming a dark-coloured horizon known as the zone of accumulation. The cementing action of the sesquioxides and humus in this zone frequently result in a hard layer known as *pan*. The depth at which the zone of accumulation occurs is dependent to a large extent upon environmental factors and the texture and lithological

character of the parent rock. Beneath this zone, which may consist of more than one coloured horizon, occurs the unweathered parent material.

The whole explanation of *podsolization* and *pan* formation is not completely satisfactory, but it is generally understood that podsolization occurs when the soil matures and becomes depleted of its exchangeable calcium through direct solution by carbonic acid water derived in the main from the decomposition of the surface organic matter. The reactive complexes in the soil thus lose basic ions in contact with this acid percolating stream, and this impoverishment proceeds to the point at which humus begins to disperse as a colloidal sol owing to the low concentration of metallic ions in the soil water. There also occur in the soil sesquioxides of iron and aluminium resulting from the weathering of silicate minerals. The sesquioxides occur in the form of colloidal gels and would be prevented from dispersion by the hydrogen ions present were it not for the protective influence of the colloidal sol of the humic matter. In this way the sesquioxides become carried down to the lower horizons by the direct influence of the percolating current. At the zone of accumulation the sesquioxides and humus become deposited with the formation of a dark-coloured band, sometimes characterized by excess of iron and sometimes by excess of humus. It has been suggested that the reason for the deposition of the sesquioxides is the alternating hydration and dehydration of the mineral organic absorption complex.

It is obvious from the manner in which this type is produced that it must be very lacking in plant requirements. Probably the fundamental cause of the poverty of podsols lies in the deficiency of the top horizon in calcium and other metallic ions. The absence of exchangeable or available calcium has far-reaching effects on the normal functions of the soil in that it adversely affects the micro-organisms of the soil and the availability of most of the minerals used by the plant for its growth. This deficiency accompanies the production of acid complexes in the soil which is prejudicial to the production of nitrate by micro-organisms. One result of this is that an accumulation of amounts of ammonia, not usually formed in other soils, occurs. It has been shown that forest soils belonging to the podsol group produce more ammonia and less nitrate than the immature or non-podsolized soils containing free calcium carbonate. It follows also that if the calcium is removed from a soil and leaching continues, other bases and ions may be leached and will leave the soil absorption complex in the reverse order to that in which they are absorbed.

The extent of the impoverishment of soil through leaching will be closely bound up with the whole environment, which includes the nature and extent of the surface vegetation. It may be regarded as certain that any factors which cause a retardation in the rate of decomposition of organic matter will also tend to produce generally an acid type of humus associated with the surface horizons. In this connexion it is known that the leaves of different species of tree, in particular those of some conifers, decay slowly with formation of humus. In this respect the character of the forest growth would influence the degree of acidity of the surface horizons and consequently the rate of removal

of basic substances. Upon this depends subsequent leaching of these horizons and their resultant poverty. There is much scope for work in this direction, as at the present time little information is available from experiments in this country to indicate the effect of forest vegetation upon the acidity of the surface horizons of the soil.

Closely connected with this problem in forest soils in this climatic region is the depth of leaf-litter accumulation. It is probably true that the natural regeneration of some woods depends more on this factor than on any other. Unlike cultivated soil, and even unlike pasture and prairie soil, the soil of the forest receives annually a large amount of organic matter in the annual leaf fall. This may lose its organic constituents at a fairly rapid rate, but the great bulk of organic matter is only changed slowly along a comparatively narrow zone where this leaf litter is in intimate contact with the underlying soil proper. The depth of this decomposition zone and the rate of decay in this region are factors of much importance from the point of view of seed germination. They must also affect the growth of the seedling in so far as they control aeration and moisture conditions in this horizon. Here again there is much room for further investigation.

The organic matter which reaches the soil in the form of leaf litter has to undergo the process of decay before it can be mixed with the soil material proper. Little is known of the factors that determine the depth to which humus penetrates into the lower horizons, though there can be little doubt that its presence there is beneficial provided always that it is not associated with extreme podsol conditions.

If it be true that extreme podsol conditions mark the natural end of most soils in this climate it is interesting to speculate as to the effect which forest vegetation has upon this process. It has been previously indicated that a necessary preliminary consists in the removal of exchangeable bases from the organic and inorganic complexes in the soil and their replacement by hydrogen. This appears to result in the destruction of soil structure and a marked impoverishment in nutritive substances in the surface horizons. Forest vegetation with its deeper rooting habit will collect its requirements from a much wider range than most small herbaceous plants. In this way there will be collected in each growing season into the trees of any area substances from comparatively low horizons in the soil. The greater part of these substances are returned to the soil in the annual leaf-fall—so much so that any student of forestry regards the leaf litter as the most important agent for soil conservation.

An examination of the amount of different substances returned in this way indicates that the basic substance present in largest quantities is lime. The amount of lime thus concentrated by forest growth on to the surface of the forest soil every year is very great, and has an important bearing upon the series of changes due to climatic factors which the soil undergoes. Most soils in this country are calcium soils, they show optimum properties when 80 per cent. of the exchangeable bases consist of lime and when the soil reaction is neutral. As has been stated, the beginnings of 'podsolization' are due to leach-

ing of calcium, which continued may lead to great impoverishment and even to formation of impervious pan layers. Tree growth by concentrating calcium and other basic substances into the surface layers will diminish the rate at which these changes occur.

Little is known of these effects except that they exist. Different species of trees, woods of different age, must each exert a different influence. It would be reasonable to suppose that different species of trees would affect these changes in two principal ways. Those species which are shallow-rooted, in so far as they effect a relatively smaller concentration, would prevent these changes less than those which are deep-rooted. The more exacting the species the greater the demand made upon the whole volume of soil and the greater the amounts of calcium, &c., which will be returned in the leaf-fall. In this way the more exacting the species, provided that it be of a deep-rooted habit, the more are the upper horizons of the soil protected from the characteristic leaching actions which appear to be the main features of soil formation in this climatic zone.

It appears to the authors that in future work on forest soil it is desirable not to omit in a consideration of such problems the natural vegetation of the forest, as the interaction between soil and tree growth is so intimate and so continuous that a consideration of one without the other may very possibly yield results which are only half the truth. It is possible to quote in support of this suggestion the experience of some demonstration plots upon what was originally very similar soil in Bagley Wood near Oxford. In this area plots of similar soil situated alongside each other are carrying crops of larch, Corsican pine, and *Tsuga heterophylla*. As a result of these different plants there have arisen in the soil specific profiles characteristic of each species of tree. In this way the extent of humification of the leaf-fall, the penetration of the humus formed, and the acidity of the soil, appear to be related to the growing crop and the environment it produces.

The main object of this article has been to indicate briefly some of the more urgent problems connected with the soil commonly believed to be typical of this climatic zone, and the desirability of further work on forest soils in the light of the more recent work carried out in soil classification in eastern Europe, and the greater knowledge which is now possessed as to the reactivity of the soil complex.

DAMAGE BY LATE FROST ON DOUGLAS FIR, SITKA SPRUCE, AND OTHER CONIFERS

BY W. R. DAY

with a note on the occurrence of *Pityogenes bidentatus*, Herbst., on frosted Douglas fir

BY R. N. CHRYSTAL

INTRODUCTION.

ONE of the great difficulties with exotic plants is to know exactly how they will withstand the climate of their adopted country. In Britain it is particularly difficult to judge this, for the climate is a notoriously changeable and treacherous one. The period of greatest danger is, perhaps, the spring when severe late frosts are liable to occur after growth has begun. Forest trees are usually only liable to severe frost damage when of a small size, that is, within the first ten years after planting out. Often the period of greatest danger is over before ten years are passed, and it is usually reckoned that when in any frost area a plantation has grown well above the height to which the cold air lies it is safe from any further serious damage. When thinking in this way, the type of frost damage in mind is that which results in a die-back of the leading shoots of the main stem or lateral branches. It will be seen in the course of this paper that this is not the only way in which serious loss may be caused by frost, and that upon occasion localities which are not usually considered to be bad frost areas can be among those to suffer most severely. The spring of 1927 tested the hardiness of our exotic conifers very greatly, owing to the severe late frost which occurred over the whole country. In Oxford this frost lasted from 27th April to 1st May. The minimum shade and grass temperatures for this period are given in Table 1. The Radcliffe Observatory is situated within the city of Oxford at a similar elevation but in a rather more sheltered position than Kennington nursery, which is just outside the city boundary.

TABLE 1. *Record of Temperatures during Period of Frost*

Date.	*Min. shade temperature at Kennington Nursery.*	*Radcliffe Observatory.*	
		Min. shade.	*Min. grass.*
April 25	44·0° F.	43·8° F.	38·8° F.
„ 26	37·0 „	35·3 „	31·5 „
„ 27	29·0 „	32·9 „	24·7 „
„ 28	31·0 „	33·4 „	27·8 „
„ 29	39·0 „	41·0 „	37·0 „
„ 30	26·0 „	28·0 „	18·5 „
May 1	28·0 „	30·4 „	21·9 „
„ 2	37·0 „	37·4 „	29·3 „
General rise in temperature after 2nd May.			

The forest trees which suffered most seriously were some of the important exotic conifers, including Douglas fir, Sitka spruce, *Thuya plicata*, and Japanese larch. Serious damage was done only in young plantations, and tended to be confined to particular areas. In the nursery some loss also took place, but not to the same extent as in plantations, for nurseries are not usually situated in places liable to serious frosting. Judging by the cases that came under observation, Douglas fir and Sitka spruce suffered greatest damage; and of these by far the worst loss was incurred with the Douglas fir.

Late frosts only affect trees after growth has begun. The cambium, the first tissue in the crown or stem in which growth commences, is the first to be liable to frost damage, and it continues to be susceptible throughout the growing season. After cambial activity has begun the flushing of the new shoots takes place. The tissues of these, both leaf and stem, being in an actively growing condition, are as a whole liable to suffer by frost, and the more or less severe browning and killing of the new growth is the most commonly observed form of damage by late frosts. There are then two ways in which such frosts injuriously affect trees. First the cambium is affected and then the newly developing shoots. The types of frost damage so produced are different and will be discussed separately, the frosting of newly flushed trees being dealt with first.

THE FROSTING OF NEW SHOOTS.

In discussing this phenomenon attention will be confined to those points of interest that have arisen as a result of the April frost in 1927.

Date of Flushing in Relation to Frosting of New Shoots. It is obvious that the date of flushing may have much to do with the amount of damage suffered by the frosting of young shoots. If all trees within one species flushed at approximately the same time it would be a simple matter to decide which particular species had the advantage in so far as lateness of flushing helped it to escape the frosts which usually occur during the spring in Britain. The existence within a single species of races or types differing from each other in date of flushing makes the matter more complicated, but at the same time gives the forester a wider choice when selecting the future crop for any particular area. That types differing in date of flushing exist must be a matter of common observation. It is, perhaps, most easily observed in the horse-chestnut. In Oxford this year the earliest tree noted of this species had its leaves one-third expanded on 6th March, while by the middle of April other specimens were still no further advanced than this. Early and late flushing types are also easily observed in the pedunculate oak, and it has been noted several times (3, 6, and 11) that the late flushing type always tends to escape damage by late frost and is therefore especially suited to some localities. Unfortunately it is also particularly liable to attack by oak mildew and to defoliation (3), and because of this is generally to be avoided. Quite recently attention has been given in Germany (4, 6, and 12) to early and late flushing types of Norway spruce. The early type is held to be the most advantageous, except in mountainous localities above 2,500–4,000 feet and in frost areas. The advantage of

the late type in frost areas can be realized from a statement by Münch (4) that in one locality, as a result of a frost on 8th June 1925, only 12 per cent. of the late flushing type lost their leading shoot, while 90–92 per cent. of the early type suffered in this way.

The existence of early and late flushing types has now been observed in Douglas fir. This is, perhaps, hardly surprising in a tree which within the range of its natural distribution includes so many different forms or varieties. These types occur, however, within one form, the green Douglas fir, and are remarkable in that here again the late type tends to escape loss of new shoots by frosting. They correspond with geographical forms already recognized as the interior dry belt and the coastal type of Douglas fir respectively, and it is found in this country that seed from trees of the former type always flush the earlier and that early flushing is a definite characteristic of them. The reason for the difference in date of flushing is doubtless to be found in the different climates under which they grow in their native country, the coastal type having an oceanic, and the interior dry-belt type a continental and alpine climate. How important this difference in habit may be is brought out by the figures given in Table 2 and obtained from trees grown in Kennington Nursery, Oxford.[1] All the four lots of the interior dry-belt type show a much higher proportion of frosted trees than does the coastal type. Even No. 4 which has suffered least shows a 96 per cent. increase on the coastal type, while in the other cases the proportion frosted is three times as great.

TABLE 2. *Injury sustained in Green Douglas Fir Plots during late Frost, April* 1927

Seed collected from.	*Place of origin.*	*Percentage frosted.*
Interior dry-belt type. No. 1	All British Columbia	79
„ „ No. 2	between lat. 49·0–°	74
„ „ No. 3	50·5° N. and long.	69
„ „ No. 4	117·0°–119·0° W.	38
Coastal type	Western coast of U.S.A.	19

The frost only killed the newly developed shoots, but the result of it was very clearly shown by the autumn in an inferior quality of plant being obtained, in which shoot growth was generally weaker and a multiple top had developed. Although there is a very great difference between the two types in the proportion of trees frosted, it is very doubtful whether there is any real difference in frost hardiness. All that can be said is that owing to the coastal type beginning growth late, it is less liable to suffer from late frosts than a type which begins growth at an earlier date. That both types are equally sensitive to frost, once growth has begun, is suggested by the appearance of frost rings of equal severity in both frosted and unfrosted trees of all the above lots. This simply

[1] This matter was brought to my notice and the counting of the plots done for me by Dr. Steven, Research Officer for England and Wales, Forestry Commission.

means that in all the trees cambial activity had begun at the time of the frost, although on some, and those the trees unfrosted to external appearance, shoot development had not commenced. The results given above show the importance of knowing the habits of different forms of a tree and of using any particular form under those conditions to which it is most suited.

The Effect of Frost on the Shoots of other Species. *Thuya plicata* was very severely affected by the April frost in 1927. In some localities the majority of the trees were entirely blackened and appeared to have suffered very severe injury. The actual damage done was, however, slight, except in frost hollows, where some trees had their leaves rather badly scorched. No opportunity has occurred to observe this species under really bad frost conditions. The general blackening after frost was, however, so remarkable as to be worth recording.

Japanese larch suffered severely owing to the frosting of dwarf shoots. This was especially noticeable owing to the dead frosted leaves hanging on throughout the ensuing summer. Very little permanent damage appears to have been done, and many of the frosted shoots showed great powers of recovery. One phenomenon worthy of note is the development of new buds around the dead growing point. These grow into rosettes of dwarf shoots or form a circle of branches according as circumstances permit. European larch also suffered severely by the frosting of dwarf shoots, and in some cases it seemed that dwarf shoots so frosted in previous years had formed centres for canker development.

THE FROSTING OF THE CAMBIUM.

Its Effects. The effect of frost on the living tissues of a tree depends entirely on its severity. If the cold is sufficiently intense death ensues, but less severe cold merely stimulates the formation of abnormal cells. Thus with regard to the cambium it may be said that two types of damage occur. First it is stimulated to make abnormal growth, and secondly it is killed and a wound formed on the stem or branch affected. As a result of abnormal growth a frost ring (fig. 2) is formed within the wood. Its place in the annual ring indicates the date at which the frost that caused it occurred. Thus a frost ring due to a late frost is found in the spring wood, and any due to frosts occurring later in the year at a corresponding position in the annual ring. Frost rings in the main stem are usually observed in small trees or in the central annual rings of larger ones. They are not usually looked for in the crown of a large tree but may sometimes be found there. Thus material of a frost-injured but still living cambium was collected on 19th May 1926 by Mr. Chalk of the Imperial Forestry Institute at a height of 35 feet up a Douglas fir. In a species the cambium of which is sensitive to frost, frost rings will be formed up to whatever height cold air lies, and in frost hollows the depth of such cold air may be very great. A frost ring usually forms a complete circle, but often only one side of the cambium is affected. Even when a complete ring is formed it can frequently be observed that the cambium has been affected much more

severely on one side than on another. This is most obvious when the cambium is partly killed and a canker develops as a result (figs. 1 and 4). The anatomy of the abnormal frost tissue can be seen from figs. 1 and 2. It is much the same in all species of conifer. Those who wish for a detailed description of it should refer to Rhoads (7) and the literature quoted by him.

The Susceptibility of Different Species. In different species the sensitiveness of the cambium to frost varies considerably. Of the conifers observed Douglas fir seems to be the most sensitive and Sitka spruce follows as a close second. Broad frost rings developed in both Japanese larch and *T. plicata* after the April frost in 1927, but no canker formation was observed. This was particularly striking in one locality where all four species occurred, but only Douglas fir and Sitka spruce developed frost cankers. It would appear, therefore, that Japanese larch and *T. plicata* are the more frost-resistant species. European larch also developed frost rings but to a much slighter extent than Japanese larch. In this respect it appears to be more resistant to frost, but there is some evidence that frost cankers on small European larch branches are much more common than is generally held to be the case; this is being studied further. The only other cankers noticed occurred on pines, in one instance Corsican pine. On two trees, just after the leading shoot had begun to grow, one side of the cambium was killed immediately beneath the leading bud, with the result that a distorted leader developed as illustrated by Rhoads (7) for *Pinus densiflora*. This type of damage appears to be rare and unimportant. In the other case a number of Scots pine transplants that were thriving badly and of a poor colour had developed a frost ring, and in some instances frost cankers, on the main stem. This type of injury is also probably quite unimportant, for the species is noted as being frost-hardy.

Canker on Douglas Fir and Sitka Spruce. Judging by experience during the last twelve months the only species that can be considered as being susceptible to a serious extent to frost damage affecting the cambium are Douglas fir and Sitka spruce. Reports of serious loss in these species have been received from the following counties: Hampshire, Gloucestershire, Somerset, Berkshire, Derbyshire, Norfolk, and Argyllshire.[1] Doubtless a close survey would show that the list could be considerably extended, but it is sufficient to show how widespread this type of frost damage was and how generally it is to be feared. In the case of a small plot of Douglas fir in Marian's Enclosure, High Meadow Wood, Glos., statistics of the loss incurred are being collected. The figures in Table 3 give the information available up to the present time. The rupturing of the bark is a sign of frost canker. It is due to callus overgrowth at the edge of the wound, and is always much more obvious in Douglas fir than in Sitka spruce. According to these figures 63 per cent. of the trees are seriously frosted, and the death-rate in the plantation as a whole is very high, twenty-two trees having died between October 1927 and January 1928. The plot is still under observation and further particulars may be obtained from it. All the dead or missing trees will not have been lost owing to frost, but

[1] Some of this information was received through Mr. J. S. L. Waldie.

many of the trees have been completely girdled and it is to these that the high death-rate is due. In some cases *Armillaria mellea* (Vahl.) Quèl., the honey fungus, has attacked trees, and it is possible that some few of the losses are due to this fungus only.

TABLE 3 [1]

	October 1927.	*January* 1928.
Healthy trees	355	309
Slightly off-colour and showing signs of rupturing of bark, mostly at butt	504	534
Bad colour and bark badly ruptured, mostly at butt	434	428
Dead or missing	201	223
	1,494	1,494

The Position of Cankers and Effect of Girdling. Frost cankers have been observed only on trees up to 10 or 12 feet high. They may occur on the branches or the main stem and at any height up the tree. In general it may be said that, judging by the effect they produce, cankers tend to fall into two classes. First there are those occurring within 2 or 3 feet of the end of the lateral or leading shoots, and second those on the main stem within 6–18 inches or 2 feet of the soil. In both classes the canker frequently girdles the stem. When this happens, in the first class, a die-back of the cankered shoots takes place and, in the second, the whole tree is injured beyond recovery. In both classes a frost ring is usually to be found throughout the tree both above and below the canker. The death of the part of the tree above the place where the branch or stem is girdled does not take place immediately. Usually there is time for at least a few rows of normal tracheids to be formed before this happens, while in trees girdled near to the ground the crown may linger on for a long time before dying. It has not been observed how long the crown of a girdled Douglas fir or Sitka spruce may live in this way, but the crown of trees girdled in the spring may easily be alive, although of a bad colour (as recorded in Table 3), by the following autumn or winter. The crown may keep alive for years in some species, for example, the crown of a Lawson's cypress girdled in 1920 was still living, though of a very bad colour, in 1924. That an affected tree has suffered some damage may, however, be seen during the following summer. By this time fungi will have colonized the dead parts; any leader affected will have died, and trees girdled near the ground become a bad colour. Also, where the stem has been cankered, and especially without girdling, the canker becomes visible, owing to the cracking of the dead covering back by the callus overgrowth. When cankers do not girdle a tree, the part affected recovers unless other factors intervene to cause death.

When may this Type of Damage be expected to Occur? The answer is: At any time when the cambium is active and the temperature sufficiently low. In Britain the spring is the period of greatest danger. Many of the Douglas firs examined were affected before flushing had taken place. There was accordingly

[1] From data collected for me under the instructions of Mr. D. W. Young, M.B.E., Deputy Surveyor Forest of Dean.

at the time the frost occurred no external sign that the tree had been in any way injured by it, and when, later in the year, perhaps the greater part of a plantation turned a bad colour and showed parts of the stems infested with bark fungi, it was often completely overlooked as the primary cause of the disease.

THE TYPE OF LOCALITY IN WHICH DAMAGE OCCURS AND THE RELATION OF SURFACE VEGETATION TO IT.

While some of the cases of this kind of damage were found in frost hollows, none of those which came under notice occurred in localities which are notoriously dangerous from late frosts. None of the localities examined were on steeply sloping ground where good drainage of cold air might be expected, but sometimes they were so situated that no drainage of cold air into them could take place. The localities were, therefore, of two types, first frost hollows of a mild type, and secondly flat areas from which the quick drainage of cold air is impossible. In some cases no previous frost damage had been observed in them, but it is to be noted that the presence of frost rings due to late frost in the annual rings of years previous to 1927 showed that dangerous frosts had occurred before. In no instance examined had these previous frosts been of sufficient severity to cause canker. Thus in a Sitka spruce in 1927 the main stem was badly cankered in several places, although not girdled. In 1926 a severe frost ring developed throughout the main stem and in 1925 a partial frost ring developed. It is of especial interest to note that this partial ring occurred on the side where two years later the cambium was killed. Careful consideration showed that, taking the localities as a whole, the more serious damage was not to be associated with the collection of cold air in any particular area. Frost rings might arise owing to this, and cankers causing the die-back of shoots also appeared to be associated with it, but not the severe cankering with or without girdling of the lower part of the main stem, which has been by far the most serious cause of loss. In every locality examined this type of damage has been associated with a surface vegetation in which grass dominated, with or without rushes, and it is here that the cause of the trouble must be looked for. Wherever a different surface vegetation existed, such as bracken or bramble, the damage was either very much less severe or failed to occur at all.

This correlation between the presence of a ground flora of short thick herbage and the production of frost cankers can be most marked. For example, in a small plot of Sitka spruce in Bagley Wood, Oxford, the trees seriously frosted always stood in small islands of grass in the midst of the bracken and bramble which otherwise constituted the dominant ground flora. The bramble and the dead bracken stems undoubtedly gave protection against frost, while the grass increased the danger from it. Similarly in a Hampshire plantation of Douglas fir the trees that had escaped damage stood in small areas of bracken or bramble, very clearly marked out from the remainder of the plot in which grasses and rush dominated. The small area of Douglas fir from which the data for Table 3 were obtained showed a similar state of things. Here in July it could easily be seen that the trees that had suffered least stood in the midst

of bracken and bramble, as contrasted with a dominant ground flora of grass, for the rest of the plantation.

When the external damage due to frost occurs within a particular zone, it must of necessity be assumed that it is within this zone that the most severe frost occurs. Thus when frost cankers occur generally, as shown in Table 3, on the lower part of the stem it is the air surrounding this part and standing immediately over the ground that was coldest and its low temperature that is the cause of the death of the cambium. The occurrence of this zone of specially cold air is to be explained by the minimum grass temperature. If the figures given in Table 1 for the minimum shade and grass temperatures at Radcliffe Observatory are examined it will be seen that on 27th April the minimum grass temperature was 8·2° F. below the minimum shade temperature, while on 30th April it was 9·5° F. below and reached the minimum temperature for the period, 18·5° F. On higher and more exposed sites than that on which this observatory stands the temperature was probably three or four degrees lower still.

Staudacher (10), confronted with a similar problem in connexion with Norway spruce, also came to the conclusion that the low temperatures occurring over grass were the cause of much severe frost damage. He found that the lowest temperature occurred at the tips of the grass blades. It has not been possible to check this, but the fact that no cankers have occurred nearer than about 6 inches to the surface of the soil suggests that he is right.

The importance of the ground flora can be stressed further by citing another case in Bagley Wood. Here a plantation of Douglas fir stands in a frost hollow. The ground flora is chiefly thick bramble, with a few small birch and willow as weeds, and in some places bracken. It is noticeable that the common type of frost damage is a die-back of the shoots, and that cankers low down on the main stem are rare. Such frost cankers as do occur have been found above the level of the undergrowth and chiefly on branches. Obviously here the thick undergrowth, in so far as it is able to cover the trees, is acting as a protection against frost.

THE RELATION BETWEEN SILVICULTURAL TREATMENT AND FROST DAMAGE.

After the felling of an old crop, is any indication ever given that the conditions of the soil change so as to increase the danger from frost damage? The answer is that in localities where frost cankers are liable to develop such can sometimes undoubtedly be found. The Hampshire Douglas fir plot above mentioned is a case in point. This plot stood at the foot of a slope, the upper part of which was planted with larch. The ground gently sloped away from the Douglas fir, and was covered with oak-high forest such as the conifers had replaced. A small stream ran down the hill-side, and the ground on either side of this, and around the springs from which it arose, was at the time of felling the only definitely wet or marshy soil. For this reason it alone was planted with Sitka spruce. At the time the plot was examined the Douglas fir were 6–9 feet high and up till 1927 had done exceedingly well. The plot as a whole had, however,

largely become invaded by rush, and there was every sign that since replanting the soil had become definitely more wet and less well drained. The felling of the old crop had evidently resulted in a raising of the water-level and an increase of the water content of the soil, and due to this change in water conditions, a change in ground flora was coming about. Bracken was entirely, and bramble chiefly, confined to the better-drained parts of the area where the soil was warmer and drier, and it was in these parts that the frost had done least damage. The interpretation of this is that there are certain sites in which, after clear felling, the soil will definitely become more cold and wet, and on which an unfavourable type of ground flora will develop. This will tend to turn the site into a potential frost area, unless precautions can be taken to prevent such a development. The researches of Burger (1) into the physical condition of the soil lead one to expect that this should be. He found that after clear felling the soil became more compact; its air content decreased, and that in many cases there was a definite increase in water content. None of these developments can usually be considered good for the growth of the new crop, although often they may be so slight as not to cause any noticeable difference to it. But where good drainage of the soil depends on the presence of a standing crop they can be very important, and changes such as those indicated may often be seen. Close observation of a locality will sometimes show where they are to be expected, and then every precaution should be taken to prevent deterioration in soil conditions, and the development of a frost area.

THE PREVENTION OF DAMAGE DUE TO LATE FROST.

Out in the forest die-back or canker due to frost is only likely to occur in particular areas, but within these areas much trouble may be experienced, and considering their size, no inconsiderable loss suffered. Fabricius (2), writing on Sitka spruce in Denmark, remarks on the occurrence and prevention of frost damage. There, spring frosts are apparently of little consequence except on flat areas, such as heaths, or in hollows at a distance from the sea, where the danger may be great. A thick covering of grass is said to increase the danger of frost damage. In substance this agrees with experience in this country and is confirmation of what has been said above. He further states that where there is a danger from frost, an advance crop of birch helps to give protection. In some cases, as on poor heaths, nurses of mountain pine are used for the same purpose. When planting up frost areas in this country it may also be found useful to have nurses, or at least to leave any growth standing that is capable of giving protection against frost. Sometimes it will also be necessary to drain an area in order that the soil and ground flora may be maintained in a favourable condition so far as is possible. Apart from this the only thing to do is to chose a species that is not sensitive to late frosts, and often this will be preferred as being least troublesome and expensive. It is here that late flushing varieties of trees may prove to be a great advantage. What is actually done should be that which will produce the most profitable crop; but the determination of this is a matter for experience and to be decided by those with a knowledge of local conditions.

FUNGI AND FROST DAMAGE.

It is, of course, generally known that frost-injured parts provide one of the most common types of infection centre for parasitic fungi. These fungi are usually facultative parasites, capable of living as saprophytes, and often are only dangerous when their host has been injured, as by frost, or reduced in vigour by some other means and so unable to resist attack. During the summer after a really severe late frost it is common to find parts of young trees dying back. This is apparently due to fungous attack, and only on close examination is it discovered that the primary cause of the trouble has been frost. Unless the possibility of frost damage is borne in mind it is quite easy to consider the fungus as the first cause of disease, and in many cases this has been done. When a die-back occurs from the tips of the shoots downwards, frost is naturally thought of as a possible cause of damage, but when the sole damage is a canker on the main stem this is not so obvious. It has to be remembered that such cankered trees often show no signs of distress until well into the following summer. It is quite possible in some cases for them to live for several years after complete girdling, and yet show no more sign of distress than an abnormal colouring of the leaves. Here then frost is often not suspected, and the dead bark, colonized by a fungus known to be associated with the die-back of trees, may be blamed for the trouble. In the case of the Douglas fir and Sitka spruce examined during the last year, one of two fungi, *Myxosporium abietinum*, Rostrup (8 and 9), and *Phomopsis Pseudotsugae*, Wilson (13), were always found on the frosted parts. They never spread beyond the tissue killed or very severely injured by frost, unless the tree as a whole was so badly affected that it must in any case die back to a very great extent. The trees examined undoubtedly showed that these fungi were not acting as virulent parasites, and that any tree in a reasonably vigorous state could resist them.

Apart from these fungi affecting the bark of the crown, *Armillaria mellea* sometimes occurred, but also only as a secondary parasite, destroying trees already much weakened and in some cases dying. In a European larch it was obvious that frost injury assisted in the spread of this fungus within the host. The fungus had apparently entered the root of the tree during the previous late autumn or winter, for the 1926 annual ring in the root was completely formed. It had, however, only spread up the tree on the side on which frost injury was greatest. Frost had not killed this tree, but only caused the development of a frost ring at the beginning of the spring wood. Abundant traumatic resin ducts had developed, undoubtedly as a result of the fungous attack.

The occurrence of *Pityogenes bidentatus*, Herbst., the two-toothed pine beetle, on frosted Douglas fir

This beetle may provide a further complication to the problem of disease control. It was found working in the stems of young Douglas fir from King's Lynn, Norfolk. The plantation affected was set in a hollow on the top of a hill and surrounded by an older plantation of conifers. It was therefore in

a possible frost area. The tree sent for examination showed very typical frost cankers (fig. 4), and it was in these frosted parts that the beetle began to work. Apparently its attack upon the tree commenced last year, as only one brood tunnel was found (fig. 3), from the neighbourhood of which six adult beetles were recovered, four males and two females, no larvae or pupae being present. The exit holes of several other beetles were observed in the bark and another female was found boring into a green and resinous branch node slightly higher up the stem. The gallery system which covered an area of about 5 inches in a vertical direction completely encircled the stem and showed two well-marked mother galleries, the third being rather indefinite. The beetle in this case is evidently following closely upon the frost and fungus damage, and will probably increase the scope of its attacks during the present season if left unchecked. This type of secondary damage to young coniferous plantations is referred to by Dr. Munro (5) in his bulletin on British bark-beetles. Scots pine and spruce are the most common breeding-hosts of the beetle, but larch, silver fir, *Thuya*, and Douglas fir are also attacked.

SUMMARY.

(1) In this paper is discussed the effect upon certain exotic conifers of the severe late frost that occurred at the end of April 1927, Douglas fir and Sitka spruce being the species chiefly concerned.

(2) It is shown that the frost caused three types of damage: (*a*) it killed the newly developing shoots, (*b*) it killed the cambium, or (*c*) caused the formation of a frost ring.

(3) The effect of frost on newly growing shoots is discussed in relation to Douglas fir. The green form of this tree is shown to have early and late flushing types corresponding to those forms already known as the interior dry belt and the coastal type respectively. Only 19 per cent. of the late type had their shoots cut back as compared with 39–79 per cent. of the early type.

(4) The effect of frost on the cambium resulted in the development of large frost rings in Douglas fir, Sitka spruce, *T. plicata*, and Japanese larch, and sometimes in smaller frost rings in European larch.

(5) Douglas fir and Sitka spruce, but not the other species, also suffered severely owing to frost killing the cambium and thus causing cankers, many of which girdled the stems affected.

(6) The girdling sometimes resulted in a die-back of the leading or lateral shoots, but the most serious loss was caused by cankers girdling the lower part of the main stem and thus entirely ruining the tree.

(7) This type of frost damage does not show at once, and the subsequent dying-back of trees affected is frequently put down to parasitic attack by fungi which colonize the frosted parts. The fungi found on Douglas fir and Sitka spruce have been *Myosporium abietinum*, Rostrup, and *Phomopsis Pseudotsugae*, Wilson. In this case both have been acting as secondary causes of disease, and have shown no signs of being virulent parasites.

(8) Frost-cankered Douglas fir have also been attacked by the two-toothed

pine-beetle, *Pityogenes bidentatus*, Herbst., which also acted as a secondary parasite colonizing the frost cankers in the first place and attacking green parts of girdled trees afterwards.

(9) The cause of the cankering of the lower part of the main stem is shown to be due to the low temperature of the air lying immediately over a ground flora in which grass dominates. On the other hand, where the dominant surface vegetation is bracken or bramble or of a similar type, protection is given against frost.

(10) Evidence is brought forward to show that in certain localities clear felling may so adversely affect soil conditions as to favour a bad type of surface vegetation and cause the development of an area in which frost canker will occur.

(11) If this type of damage is to be prevented careful attention must be paid to drainage, and if necessary regeneration should be carried out under an advance crop of such a species as birch. If this is not profitable a frost-hardy species must be used.

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EXPLANATION OF PLATE I

Fig. 1. Frost canker of Douglas fir in cross-section, and showing frost ring and traumatic resin ducts. × 4 times.

Fig. 2. Enlargement of frost ring in the same tree. × 30 times.

Fig. 3. Galleries of *Pityogenes bidentatus*, Herbst., in frosted Douglas fir stem. × ⅓ times.

Fig. 4. Douglas fir stem in cross-section, showing frost canker. In the 1927 (the latest) annual ring is a broad frost ring. At the beginning of the 1926 annual ring is a much slighter frost ring, which is marked by the slightly darker colour. × 1⅓ times.

Fig. 1

Fig. 3

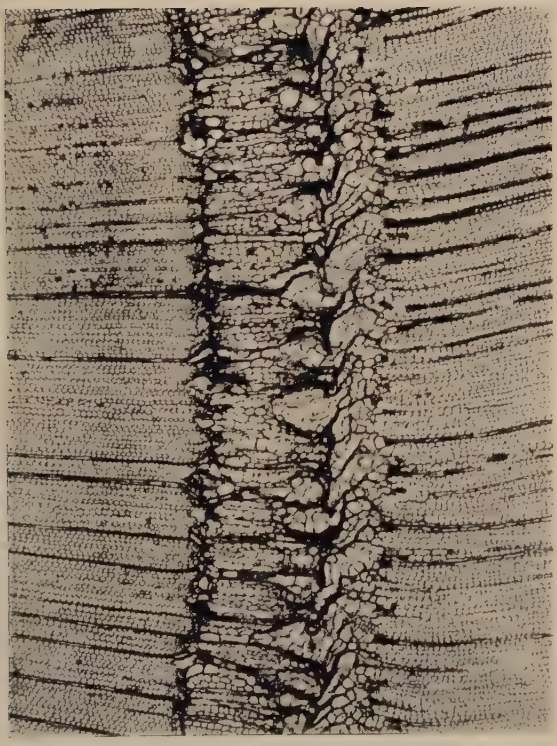

Fig. 2

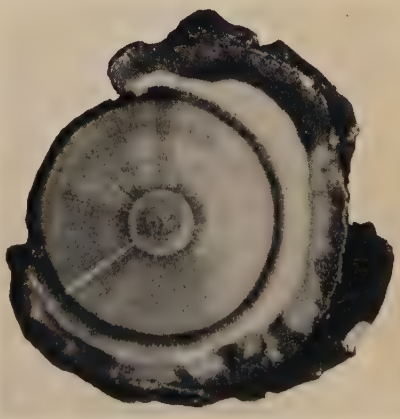

Fig. 4

PLATE I

THE BIOLOGY AND CONTROL OF *HYLOBIUS ABIETIS*, L.

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Part I

THE genus *Hylobius* is a small one, including only four species which are recognized as of interest or economic importance in forestry. Three of these occur in Europe, namely *H. abietis*, L., *H. pinastri*, Gyll., and *H. piceus*, Deg. The last-named is of minor importance; and *H. pinastri* is by many authors considered to be merely a variety or smaller form of *H. abietis*. If a long series of specimens of *H. abietis* be examined considerable variation in size, form, and sculpturing is found, although the character of the genitalia is uniform, and the writer agrees with Escherich and others in regarding the validity of *pinastri* as doubtful.

In the eastern United States *Hylobius pales* has recently assumed importance, playing the same part in relation to replanting of felled pine plantations as *H. abietis* does with us. Its biology and habits as described by Peirson agree very closely with those of *abietis*.

In Britain *H. abietis* is our only species. It is now widely distributed both in this country and in Ireland. Until about thirty years ago it was relatively rare in England, and there is good reason to believe that during the past thirty years it has made its way south from Scotland and is increasing in districts where it was formerly unknown. That it has occurred on the Bagshot sand pine districts for many years is certain, but its occurrence in the eastern counties and in the midlands is almost certainly recent.

This wider distribution of *Hylobius* has been brought about not by the actual migration or dispersal of the weevils themselves, but by the transport of timber conveying larvae and pupae and, perhaps, adults into new districts. The occurrence of the weevil at Corrour in Inverness-shire in the heart of mountainous treeless moorland can be explained only by its introduction in telegraph poles and other timber brought into the locality either by the railway or for Corrour Lodge. The dispersal of *Hylobius* by its own activity is discussed later, but meanwhile it may be said that all the latest evidence tends to show that over long distances the main mode of dispersal is by the transport of timber.

On the status of *Hylobius* as a forest pest there is an extensive literature, mainly German, but in spite of this the general relationship of the weevil to forestry practice and the conditions which favour its increase are still incompletely understood. It is hoped that the observations and experiments here

described may help towards a better understanding of the weevil problem and towards a more rational system of control. They are the outcome of a long and close experience of the weevil problem as it presents itself in our peculiar forest conditions, and in particular of experimental control work carried out on behalf of the Forestry Commissioners during the period 1919–26. Acknowledgements are due to the Commissioners for the facilities given for the work, to their Divisional Officers on whose areas experimental work was done, and in particular to Mr. J. F. Annand of the North-East (Scotland) Division whose kindly help and interest made possible such ecological work as has been carried out.

BIOLOGY.

The most important features in the biology of *Hylobius* are the longevity of the adult, the production by the female weevil of several broods over a period of three or even four years, and the consequent variation in the length of the life-cycle from egg to mature adult depending on the date of egg-laying, eggs laid in early summer resulting in rapid development, eggs laid in autumn resulting in slow development.

The longevity of the *Hylobius* adult was first recognized by von Lips and Zimmerman in 1854–8. Their observations were confirmed by von Oppen in 1883, but it was not until 1897–8, when MacDougall and Nüsslin studied longevity and reproduction in the *Pissodes* weevils, that the full import of these features in *Hylobius* and in *Pissodes* was fully appreciated. In *Hylobius* longevity is even more important than in *Pissodes* from the forester's point of view, because while the *Pissodes* weevils are injurious chiefly in the larval stage *Hylobius* is injurious in the adult state, and its long life as an adult makes it the more serious pest. In fact, it is because *Hylobius* is sexually immature when it assumes the imaginal form and feeds to become mature, and because after its first breeding it feeds again and proceeds to a second egg-laying, and again after feeding to a third or even fourth egg-laying, that it is so serious a pest in young plantations.

For these reasons, while the habits of the larva and the effects of such factors as temperature and humidity on its rate of growth and development are of great interest and some importance, the habits of the adult are much more interesting and much more important. Moreover, until the habits of the adult are understood the greatly varying rates of development of the larvae, even in one and the same pine stump, root, or log, cannot be explained. Escherich, for instance, has shown that the period of development of the larva may vary from six months to twelve even where feeding conditions are equally favourable in both cases, and for many years this variation in rate of development has been a frequent subject of discussion in the German forestry journals.

The habits of *Hylobius* which are of special interest in relation to the control measures practicable against it are: hibernation, feeding habits, and mode of egg-laying.

HIBERNATION OF *HYLOBIUS*.

Hylobius hibernates in the upper layers of the soil, either in the humus layers or just below them, and in sandy localities at some little depth in the soil itself. In the colder winters of the north of Scotland the weevil is inactive from October to April, but in the milder climate of the south of England it becomes active during very mild weather such as is not infrequent in late January or early February. The temperature factor is the chief agent determining the retiral of *Hylobius* into winter quarters and its emergence from them. In my laboratory at Kew I carried out in 1922 some simple experiments on the effect of temperature on the activity of *Hylobius*. In the control cages the temperature ranged between 43° to 47° F. with an average of 45°. In these the weevils, which had been collected early in February in soil below fallen pine logs at Bagshot, remained in the soil, and showed no activity until 11th April when the outdoor temperature rose. After that date the experiment was closed.

In the experimental cages the temperature was raised and lowered from 43° to 65° F., and the behaviour of the weevils at different temperatures was noted. At 49° F. the weevils began to appear above the soil, and when the temperature had risen to 65° all had come up and showed great activity. Several paired and all nibbled at the food plants.

The experiments were continued during March and April, and it was found that at temperatures between 49–50° the weevils became active, and at 60° even flew off the sides and roof of the cage. When on 11th April the warm weather set in with an outdoor temperature of 58° F., egg-laying had begun in the experimental cages and continued till 28th May.

These experiments, although carried out on the simplest lines, afford a useful guide to the behaviour of *Hylobius* weevils in the field. Their results correspond closely with those of field observations at Bagshot in Surrey, Hawkhill in Hampshire, Montreathmont Muir in Angus, and at Culbin Sands in Morayshire. Thus in 1922 at Bagshot in April and May weevils were actively feeding, while in Angus and Morayshire the weevils became active only during the first fortnight in May, the first weevils being found in Angus on 3rd May.

Throughout my experience of *Hylobius* I have found that this weevil is very sensitive to weather conditions, of which temperature is the most important factor. Whether in searching for weevils in early spring, or in summer in some hitherto unexplored area, or in looking over records of trapping, the same important effect of temperature has been evident. On warm days the weevil is active; on colder days it is sluggish and buries itself under the soil covering, or even in the soil itself.

The effect of temperature on the weevil's activity is well borne out by trapping records made on felled areas. Such records of the numbers of weevils collected from billet traps—the most generally efficient type of trap available—in such distant and different localities as the New Forest, Culbin Sands, and Port Clair (Inverness-shire), for example, all show a slow and gradual rise in numbers during May, then an abrupt rise during June in England and during

June and July in Scotland, and then a gradual decline until in September and October no weevils are found.

Such trapping records become still more interesting if dissection of a percentage of the weevils trapped can be made in order to examine the reproductive organs. In May and early June female weevils trapped in many different localities all showed shrivelled egg-tubes. These were hibernated weevils. In June and July female weevils occurred in ever-increasing numbers and higher proportion which showed undeveloped—i.e. unripe—egg-tubes, while others occurred showing rapidly developing egg-tubes.

At Bagshot and at Hawkhill, where the winter is milder than in the north, weevils trapped in May frequently showed developed egg-tubes, indicating that they had fed intermittently in mild early spring weather or during the previous autumn.

All my observations indicate that the first weevils to appear in spring are old weevils, weevils which have spent one or more summers in the open or have emerged in summer or early autumn of the previous year. Later these are joined by weevils just emerged from the pupal beds where they have passed the winter either as adults or more rarely as pupae. Confirmation of this interpretation is obtained from experiments at Hawkhill Inclosure in the New Forest. In this area a series of pine belts was left during a felling in 1917. These were due for cutting in 1923, but the cutting was done irregularly and the area therefore consisted, in spring 1924, of belts of standing timber with irregular felled belts. In that year trapping was begun, and the interesting feature of the records was that they did not show the gradual and then rapid rise in numbers followed by a slow decline. They showed an irregular rise and fall within quite narrow limits, namely a rise from 50 to 120 per day, then a fall to 60 and a rise to 80 and further fall to 40, and so on until in July a final fall occurred and the numbers never rose again. I examined several batches of the weevils collected and all were old weevils. This was almost more than I dared hope for, because I had recommended trapping at Hawkhill as a means of checking breeding in the felled belts on the assumption that such weevils as occurred in the felled belts were part of the normal population of these belts, and the relic of an enormous population which had arisen there as a result of felling in 1917 when these belts were left. My dissections combined with the records which showed a complete fall in numbers early in July confirmed my view, but more interesting confirmation is available from the trapping records for 1927.

Since 1924 felling has been going on steadily at Hawkhill, so that the area, which in 1924 was to be regarded as standing wood with here and there a patch of felling, had in 1927 become a felled area with patches of standing timber. The change is noteworthy and the 1927 records amply illustrate it. For these records I am indebted to Mr. R. N. Chrystal, who visited the area in July last and kindly gave me a copy of his report containing the records. These records show a rise in numbers from 70 on 2nd April to 750 on 16th April. On 30th April 1,400 had been taken; on 14th May 2,786 had been taken; and then

the numbers gradually fell to 1,870, then to 970, and then remained more or less steady until 18th July when the records close. Here we have the weevil chart for the felled area with older weevils appearing first and young weevils appearing later to swell their numbers rapidly. Unfortunately, we have no dissections to complete the records, but I am satisfied that my interpretation of them is correct. In fact at Hawkhill, as I show more fully later, we have valuable evidence showing how a weevil outbreak arises and develops. One thing, however, must be borne in mind, namely that at Hawkhill trapping has been intensively and ably carried out, and that the rise in number of weevils trapped as shown by the 1924 and 1927 records—a rise from 150 to 2,780 or approximately twentyfold—is much less than would occur where no trapping was done. I refer to this later in dealing with control work.

FEEDING HABITS.

After hibernation comes activity and feeding on the part of the weevils. To most foresters this means destruction of young newly planted conifers, but to the biologist it has more importance and greater interest. In the first place feeding precedes egg-laying, and the two functions are closely associated.

The general opinion that *Hylobius* weevils feed mainly on young plants on felled pine areas is unsound biologically. The weevils feed on fallen tops and branches lying on the soil, on the leaders and side branches of young larch and spruce trees 15 or 20 feet high, and in the tops of pines 40 or 50 or 60 feet in height. In fact *Hylobius* feeds on the young bark and cambium of any woody plant, preferring conifers. In my experimental work I have fed weevils on most of the conifers commonly planted in Britain, including the swamp cypress (*Taxodium*) and yew, and I have fed them on twigs of hazel, birch, hawthorn, and oak, and on the dry woody stems of old heather or ling. On all of these plants they will feed, and provided the plants are fresh will thrive at least for a time.

The main natural food of *Hylobius* is the Scots pine, and it is not commonly known, nor is it, so far as I know, even recorded that *Hylobius* is responsible for a malformation of the crown of the Scots pine corresponding to the malformation produced by the bark-beetle *Myelophilus*. I first observed this malformation and ascertained its cause on Monaughty Moor in Morayshire. On part of the moor a crop of Scots pine had been felled, but many small trees had been left and some of these showed a flattened crown with numerous short leading shoots all of which were gnawed off. On these pines and on others near by the weevils were feeding. They preferred these older pines to the young crop just planted beneath them. On the Culbin Sands the curious stunting effect of the weevils' feeding was even more evident, and on that area one could pick out and distinguish at a distance those pines which had been pruned by *Hylobius* and those pruned by *Myelophilus*.

At Bowmont Estate near Roxburgh I found *Hylobius* weevils feeding on the leading shoots of Japanese larch 12 feet above the ground. The weevils had come from a felled, but unplanted, pine area adjoining. In the course of my

field work I have had many opportunities of examining recently felled trees for evidence of *Hylobius* injury on the young shoots of the crown and branches, and I have been surprised to find how frequently such feeding can be detected.

Hylobius, when feeding, nibbles off the drier outer bark and then nibbles deeply into the cambium. It discards the drier bark which can be found lying at the base of the plant or below the log or branch on which it is feeding. Once the cambium is reached the weevil bores in it undermining the outer bark, and then levers off this outer bark with its snout. The final result is the pock-like markings so well known to the forester. The *Pissodes* weevils when feeding merely puncture the bark and probably feed on almost liquid food, and their 'frass' is readily distinguished from that of *Hylobius*. They undermine the bark but do not lever it off as *Hylobius* does.

The pine sawflies *Lophyrus* (*Diprion*) *pini* and *rufus* also gnaw young pine twigs, but their 'frass' is more extensive than that of *Hylobius* and does not have the pock-marking appearance. Where sawfly caterpillars have been at work marked nibbling of the pine needles is also to be found, so that *Hylobius* 'frass' on pine twigs is fairly easily recognized.

The feeding habits of *Hylobius* suggest a stage in the evolution of the bark-boring beetles. The weevils gnawing punctures in which to oviposit appear to have found food at the same time, and the egg-laying habits and feeding habits are probably more closely associated than is commonly realized.

If, as we may suppose, the feeding habits have arisen from the weevils gnawing small punctures in the bark of roots, fallen stems, and branches of pine in order to place their eggs in conditions suitable for the larvae, we can readily understand why billet traps are so attractive to the weevil not only for oviposition but also for feeding purposes.

EGG-LAYING HABITS.

The most important feature of oviposition in *Hylobius* is the weevil's choice of stumps or roots below soil level or of branches and stems lying closely pressed to the soil. This is most strikingly shown when, in felling, the roots of a pine are torn up, exposing them above soil, or when trees are uprooted by wind. In such cases weevil eggs or larvae are found abundantly on such roots as remain buried, but on those roots exposed above ground no eggs and larvae are found. So, too, branches broken or torn off by snow or wind and, by their fall and weight, partially embedded in the soil are found to harbour weevil larvae in the portions embedded in the soil or in close contact with it, but those portions not in contact with the soil are found to be free. Only in one instance, on Countesswells estate in Aberdeenshire in September 1912, have I any record of *Hylobius* larvae found in the stem of a pine tree above ground. In this instance the tree had fallen and was leaning against other standing pines and contained a *Hylobius* larva about 4 feet from the base of the stem.

Experiments carried out at Kew in 1922 showed that moist moss, moss litter, or soil forming a bed for pine logs, were readily sought for egg-laying by the weevils. In cages where the moss or soil dried out, eggs were found laid

at random in the logs just as in other cages in which moss and soil were wanting. It was found that where logs or pieces of bark dried up, eggs laid in them failed to hatch, or young larvae, which emerged before drying had advanced too far, shrivelled and died when the dry conditions became extreme.

Evidently moist conditions are essential for the success of egg-laying, and it is probable that these conditions affect the welfare of the weevil larvae not only directly but also indirectly through the food supply. This aspect of larval growth deserves close study. If Buchner[1] (1927) is correct in his description of the occurrence of certain fungal or bacterial glands or sacs opening into the oviduct of *Hylobius*, and if it is confirmed that these glands result in the smearing of the egg with fungal or bacterial bodies and so in providing the young larvae with a digestive ferment, then we can readily understand the importance of moist conditions for larval development and we can further understand why stumps, roots, and fallen branches are favoured by the weevil. In any case both field observations and experimental work show that moist conditions and proximity to the soil or inclosure in it are sought by the weevil for breeding purposes. Such conditions are most easily found in standing woods and, as we shall see, there is some evidence to show that *Hylobius* will migrate from bare clearings to standing timber.

In 1922 I carried out, with the help of the forester, Mr. Colwill, at Montreathmont Muir some experiments to ascertain the behaviour and movements of adult weevils. The original intention of the experiments was to determine how far ditches or drains were an obstacle to the weevil, and also to what extent the weevils wandered from their breeding ground.

The area on which the experiments were carried out consisted of 240 acres, part of which was moorland clothed with short young heather, and part of it, some fifty acres, was recently cleared pine wood. To the south of this area was an extensive area of felled pine bordered on east and west by standing pine. To the north was open pine woodland. To the east was a long extent of bare moorland and to the west was a high road, on the further side of which was a fairly dense and wide belt of pine.

One thousand male *Hylobius* were released on this area on 3rd July 1922. Before release they were painted on the wing-covers with a paint consisting of powdered carmine and gold size. This paint in no way interfered with the weevils' movements and in no way affected their well-being, as a number of control specimens showed, and as is also shown by the results of the experiment.

The method of experiment was to trap the weevils by a series of billet traps arranged in rough circles, at varying distances from the centre of release. This served satisfactorily up to a point, but as the paint rubbed off the elytra after a time, and because close examination of all weevils trapped was therefore necessary for the recognition of painted specimens, it is certain that many of these painted weevils were overlooked. In spite of these drawbacks interesting results were obtained. Throughout the experiment painted weevils occurred in the traps and one was taken in 1924 two years after its release, a fact which

[1] See page 130 for a review.

affords proof of the weevil's longevity under natural conditions, and which suggests that the weevils are more or less sedentary in a wooded locality.

The most interesting result of the experiment was that the majority of the weevils recovered were taken west of the point of release, and that most of these occurred in the series of traps bordering the high road on the other side of which lay the dense belt of pines. The maximum distance traversed by the weevils as shown by the trapping records was about 800 yards. Other results obtained were that ditches or drains, burned heather, rough overgrown heather, and sandy tracks and roads offered no obstacle to the weevils, that pine billets if partly embedded in the soil were very attractive traps, and that male weevils are equally attracted to such traps as are female beetles.

From general observations made during this experiment it is safe to assume that there was on this area a definite movement of the weevils between the felled area and the standing woods and vice versa. One important fact was established beyond all doubt, namely that the felled area did not attract all the weevils in the vicinity to it. In the pine belt on the west of the felling snow had caused a bad breaking of branches, and those which had lodged in the soil harboured both weevil larvae and adults, including two painted weevils. One other interesting fact may be mentioned, namely that in moving from the felled area to the standing timber the weevils wandered in a direction contrary to the prevailing wind which was westerly.

I intended to repeat this experiment on a larger scale in 1923, but an extensive outbreak of fire south of the area prevented it, and no further experiments were undertaken. This fire itself, however, afforded an opportunity to study the effects of charring of stumps on egg-laying, and confirmed observations made on this subject at Shave Green in the New Forest. On examining a belt of young pines about twenty-five years old which had been charred and killed by the fire, it was found that these charred pines harboured many weevil larvae, and that eggs were deposited by the weevil in places where it had to bore through charred bark in order to reach the cambium. At Shave Green in 1920 I had found that charred stumps were preferred by *Hylobius* to uncharred stumps, and my experience on the burned area at Montreathmont Muir shows that burning or charring of stumps is no deterrent to *Hylobius*.

ORIGIN AND DEVELOPMENT OF A WEEVIL OUTBREAK.

From my observations made during field work in many parts of the country, from the records of experimental control work superintended by myself, and from records of similar work conducted by Mr. J. F. Annand and other officers and foresters, I have been able to piece together a reliable picture of the origin and development of *Hylobius* outbreaks as they occur under our woodland conditions and forestry practice.

In the first place these records establish the fact that weevil outbreaks arise from the presence of weevils in standing woods in the locality and in the felled area itself. Even on grass lands adjoining pine woods *Hylobius* can be trapped

by billet traps, being attracted from the woods into the open by the freshly sown billets. This is not a surprising fact to the biologist, but what is astonishing is that it should have been unrecognized and neglected by foresters, who as a class are shrewd observers.

In studying the rise of a *Hylobius* outbreak we must therefore consider first the weevil conditions prevailing in the pine wood before it is felled. At Hawkhill in the New Forest my records show that standing woods harbour a small weevil population, that with felling that population finds increased breeding ground, and that in consequence the weevils rapidly increase in numbers until they become a serious menace to all attempts at replanting.

I propose in the second part of this article to deal more fully with this question, but meanwhile I should like to emphasize the need for a study of the insect population of standing woods, especially that part of it comprising the weevils and the bark-beetles. In 1925 Dr. H. M. Steven kindly arranged for me that certain thinnings in some of his experimental plots near Bagshot should not be removed until early summer. In the plantations in question (Paschal Wood) the bark-beetle *Myelophilus* was, as I knew, present in some numbers although its presence was nowhere very evident. When the thinnings took place *Myelophilus* rapidly took advantage of the breeding ground thus afforded it, and by the end of May every felled stem was occupied from base to crown by egg-laying beetles. Their numbers were so great that it was difficult to believe that some invasion had not taken place.

In this instance we have an apt illustration of the importance of the normal insect population of standing woods and of the part it plays in producing outbreaks which at first appear to be inexplicable.

(*To be continued*)

TIMBERS AND THEIR CONDITION IN RELATION TO *LYCTUS* ATTACK

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INTRODUCTORY.

DURING the past two and a half years an investigation into the damage caused by *Lyctus* powder-post beetles to timber in store has been conducted by the Forest Products Research Laboratory, Princes Risborough. The investigation originated in an inquiry sent by the High Wycombe and District Furniture Manufacturers' Federation to the Forest Products Research Board concerning treatment of 'worm' in timber. The matter was referred to Dr. J. W. Munro, at that time entomologist to the Forestry Commission, who made a preliminary investigation of the conditions at High Wycombe and drew up a report. The insects causing most damage at High Wycombe were found to be species of the genus *Lyctus* (family Lyctidae), the powder-post beetles, which occur throughout the tropical and temperate countries of the world. The seriousness of this *Lyctus* problem was stressed by Dr. Munro, and at his suggestion the Forest Products Research Laboratory undertook, in co-operation with him, an investigation into the occurrence of *Lyctus* throughout this country, the causes of the increase of these insects, the damage they do, and possible methods of reducing and preventing further losses. On Dr. Munro's appointment to the Entomology Department, Imperial College of Science and Technology, the work was continued by the Forest Products Research Laboratory in conjunction with him at the Imperial College. A full report on this work is in preparation, and will be published shortly by the Forest Products Research Laboratory. During the course of the work some interesting information has been collected on the relation of *Lyctus* to different timbers and the conditions which invite attack. A brief outline of the factors which appear to govern *Lyctus* attack is set forth in this paper.

HISTORY OF *LYCTUS* PROBLEM IN BRITAIN.

It is within the past eight to ten years that the *Lyctus* problem has become so serious in this country. Where formerly only two species—and one of these rarely—occurred in this country, there are now four species to be found in timber-yards and stores in Britain. These are as follows:

Lyctus linearis, Goeze (*canaliculatus*, F.). A native of Europe.

Lyctus brunneus, Steph. A native of South America, now a cosmopolitan species and more abundant in this country than the native *linearis*.

Lyctus planicollis, Le Conte. A native of United States.

Lyctus parallelopipedus, Melsh. A native of east and south-east United States.

By far the most abundant species is *Lyctus brunneus*, recorded by Fowler (10) as rare in Britain. Evidence has been obtained which shows beyond dispute

that the increase and spread of *Lyctus* in this country is due to the importation of American timber already infested by these insects. Whole consignments of infested oak and ash from America are known to have been distributed throughout the country and are indeed still reaching our ports. Too often the timber merchant handling such timber is either unaware of the presence of these insects or does not realize their importance. Usually he gets rid of infested parcels as rapidly as possible by passing them on. Recently, however, there have been instances of refusal to accept delivery of such timber—pointing to an increasing realization by timber users of the importance of insect attack in timber. Not only is American timber (particularly oak and ash) attacked by *Lyctus*, but, now that the insect has spread throughout the country and established itself in yards, stores, furniture and other factories, English and Polish oak, English ash, and timbers other than those of American origin, are also liable to attack.

In Britain the furniture industry, which uses large quantities of imported American oak and ash, has suffered more than any other trade. The losses caused by *Lyctus* are, however, by no means confined to this one industry: wherever oak and ash sapwood is used trouble is being experienced. The *Lyctus* problem, indeed, is of first importance to the whole hardwood timber trade. The responsibility for the increase and spread of this insect throughout this country rests just as much with the timber merchant as with the timber user. Universal recognition of the vital importance of powder-post beetles to all trades and industries dealing with hardwood timbers constitutes the first step necessary to reduce the losses caused by these insects. Such a reduction would mean a great economy of material by rendering larger quantities of existing timber fit for marketing and use.

TIMBERS ATTACKED.

The mode of egg-laying of *Lyctus* beetles is the first factor determining the species of timber liable to attack. The egg is inserted within the pores or vessels of certain hardwood timbers by means of a long delicate ovipositor or egg-tube. The ovipositor, which is from 3 to 4 mm. in length, can be extruded from the body of the female beetle, and is pushed down a suitable wood vessel. Whilst it is in such a position the egg passes along the tube, and is thus deposited within the vessel. Hardwoods alone are therefore subject to attack by *Lyctus*. So far as is known, coniferous woods are never attacked, doubtless owing to the absence of vessels or pores in which the eggs could be laid. No instance has ever been recorded of *Lyctus* laying eggs on the surface of timber as does *Anobium punctatum*, the common furniture beetle. Noerdlinger (13) states, and Xambeau (17) and Bureau (5) repeat, that the eggs of *Lyctus linearis*, as distinct from those of *L. brunneus*, are deposited in cracks and fissures in the wood. It has been shown, however, during the course of this investigation, that *L. linearis* does *not* lay its eggs in such places, unless within pores exposed in crevices in the wood.

Not all hardwoods are attacked, but those with numerous large vessels are most susceptible: oak, ash, sweet chestnut, walnut are examples of timbers

which, in this country, suffer most severely from *Lyctus* attack. Altson (1) details from records in Germany and the United States, as well as in this country, a list of hardwoods in which *Lyctus* beetles are claimed to have been found feeding. Maple, sycamore, and willow are included in this list, but in the course of the present investigation no instance of *Lyctus* attack in these timbers has been noted, nor in other small-pored timbers, e.g. beech and birch. It appears that the size of the pores in a timber as compared with the maximum width of a *Lyctus* egg determines whether or no a timber is liable to attack. It is not known whether the wood of such close-grained timbers as beech and birch are definitely distasteful to the larvae, but it seems probable that the reason for their immunity is to be found in the width of the pores being too small to allow of insertion of a *Lyctus* egg. An attempt has been made to determine what relation exists between the size and number of wood vessels in a timber and its liability to attack, by comparing series of measurements of the pores of a range of timbers found attacked by *Lyctus* during the Forest Products Research Laboratory investigations with the minimum and average widths of a series of eggs of *Lyctus brunneus*.

The method of making such a comparison, together with the results, are described by Mr. Clarke, Assistant Wood Technologist in the Forest Products Research Laboratory, on page 47 of this Journal.

A glance at the graphs included in that article will indicate at once the comparative liability to attack of the different timbers dealt with. There is thus a definite correlation between *Lyctus* attack and the size and number of pores in any hardwood species.

While certain longhorn beetles (Cerambycidae) and pin-hole borers (Scolytidae and Platypodidae) extend their tunnels into the heartwood, *Lyctus* beetles normally confine their attack to the sapwood. Once the sapwood of an attacked piece of oak or ash has been reduced to a finely powdered flowery condition—the characteristic damage that gives the name of 'powder-post beetles' to the *Lyctus* species—the attack ceases and will not continue in the heartwood. It should here be mentioned that in many tropical and subtropical timbers it is extremely difficult to differentiate between heart- and sapwood: for instance, large numbers of *Lyctus* beetles have been reared in the laboratory from a log of *Diplotropis* sp. in which the attack was proceeding well towards the centre or heart of the timber. Where a piece of heartwood overlies infested sap, as may happen in a pile of timber in a yard or store, larvae or emerging adults may accidentally tunnel in the overlying heartwood, but the attack will not continue nor result in destruction of the timber as occurs when sapwood is infested. It may be assumed that, so far as the common timbers of commerce in this country are concerned, *Lyctus* attack is confined to the sapwood.

AGE OF TIMBER AND *LYCTUS* ATTACK.

A second important factor governing the liability of a timber to attack by *Lyctus* is the period which has elapsed since the tree was felled and the changes

that have taken place in the wood during that period. Powder-post damage has always been associated with recently seasoned or partly seasoned timber, but it is by no means certain how soon after felling sapwood first becomes suitable for *Lyctus* attack.

Altson (1) emphatically states that unseasoned wood is never attacked, while Snyder (16) is of the opinion that wood seasoned less than eight to ten months will not be attacked. It has been shown in our experiments that these statements are not strictly accurate, for it has been found possible to infest with *Lyctus* oak sapwood felled only a few days before exposure to the beetles. A young oak sapling felled in June 1926 was barked, cut into conveniently sized disks, and exposed immediately to adults of *Lyctus brunneus*. In October of the same year a slight suggestion of dust was visible at the entrance to several pores. This was confirmed in March 1927 and throughout the following spring and summer. These results showed quite definitely that egg-laying had taken place in June and July 1926 during the brief exposure to beetles. The development of the larvae which emerged from these eggs was slower than that of those feeding in drier and partly seasoned wood. Apparently the condition of this recently felled and unseasoned oak was not entirely suitable, but the experiments are sufficient to prove that egg-laying and subsequent larval development can take place in timber not seasoned for any appreciable time, much less eight to ten months.

The optimum conditions in wood for the development of *Lyctus* are not known, nor is there any information at present available as to when these conditions first appear and how long they persist. That they last only for a certain period is suggested by the relationship of *Anobium* and *Lyctus* to the timber they attack. These insects both attack oak, among other timbers, but there are no instances on record of their living together at one time on the same piece of timber. Apparently at some stage after felling and drying timber becomes distasteful to *Lyctus* but attractive to *Anobium*: *Lyctus* attack ceases before *Anobium* attack begins. *Anobium* is always associated with old and well-seasoned wood, while *Lyctus* occurs in recently seasoned and partly seasoned timber. The susceptibility to attack by either of these insects appears to be governed by changes that occur in wood during and subsequent to seasoning. An attempt has been made to ascertain what the conditions are which cause these changes rendering timber liable first to *Lyctus* attack.

MOISTURE CONTENT OF TIMBER IN RELATION TO *LYCTUS* ATTACK.

During the process of seasoning, wood loses a certain amount of moisture present in it when felled: changes may also occur in the chemical composition of the cell contents, but the physical structure of timber remains unaltered. There is no microscopical difference between seasoned and unseasoned wood which would indicate why *Lyctus* prefers the drier material. It is quite possible that the moisture content of the timber is of great importance in determining the degree of *Lyctus* attack. Experiments have been conducted to ascertain how the moisture content of oak affects its liability to attack by this insect.

There is a definite relation between the moisture content of wood and the relative humidity of the air when at equilibrium; Koehler (11) indicates by graphs what this relation is and how it varies slightly with temperature conditions, but that it is approximately the same for all woods. A particular relative humidity of the atmosphere gives a particular moisture content in wood. Thus, if samples of wood be placed in closed vessels, each with a constant and known relative humidity maintained by the use of saturated solutions of certain salts (Obermiller, 14), in time the wood will adjust itself to a corresponding moisture content. Advantage was taken of this to determine what moisture conditions in oak were suitable for the development of *Lyctus*.

The salts employed, the relative humidity in the different desiccators used for the experiment and the equivalent moisture content of wood (figures taken from Koehler's curves for a temperature of 70° F.), are given in the following table:

Salt.	*Relative humidity of atmosphere over salt.* *Per cent.*	*Approximate corresponding moisture content of wood.* *Per cent.*
Potassium sulphate . . .	97	28·0
Potassium chloride . . .	86	20·0
Sodium chloride . . .	75	15·0
Calcium nitrate . . .	55	10·5
Calcium chloride (crystals) .	35	7·0
Copper sulphate (anhydrous) .	10	3·0
Calcium chloride (fused) . .	3	0·35–0·5

Small blocks of the following types of oak were then placed in each vessel:

1. Freshly felled oak sapwood.
2. Freshly felled oak sapwood, oven-dried at 100° C. before being placed in jars.

Lyctus beetles were added to the series of desiccators after time had been allowed—determined by repeated weighings—for the wood to adapt itself to the moisture content corresponding to the relative humidity of the air in the particular desiccator in which it had been placed. Check samples of oak were oven-dried and weighed from time to time to indicate the moisture conditions in the jars.

RESULTS OF EXPERIMENTS.

From three series of desiccators similar results have been forthcoming. Mention has already been made of oak having been attacked within a few days of felling. Similar pieces of oak were used in the above experiments and again it was found that *Lyctus* could attack it when green and with a moisture content of as much as 40 per cent. Eggs were laid and development of larvae followed in samples of wood in the above experiments, with moisture contents varying from 28 per cent. to 10 per cent., irrespective of whether the samples had been placed in the jars just after felling or first of all had been oven-dried and allowed to reabsorb moisture from the atmosphere before being exposed to attack. It is significant that where the moisture content of the oak fell

below 8 per cent. the samples were not attacked. Apparently a higher moisture content is more favourable for *Lyctus* than a very low one. It is not yet possible to state how the moisture condition affects the rate of development of the larvae, but the experiments have proved conclusively that eggs can be laid and larvae feed in comparatively moist oak.

A further point of interest brought out by the experiments is that oven-dried oak sapwood, allowed to take up moisture from the air before exposure to beetles, was attacked quite as readily as oak which had not been dried. If some chemical change takes place in the drying and seasoning of timber, this alone apparently does not determine whether or not it will be attacked by *Lyctus*.

DISCUSSION.

While variations in moisture content of wood affect its liability to attack, how such changes bring about the requisite conditions in wood is still to be ascertained. Little can be said until it has been shown what constitutes the food of *Lyctus* larvae. Work on this subject is now in progress in co-operation with the chemistry and mycology sections of the laboratory. Meanwhile it is of interest to note that Baumberger (3) has shown that although *Sciara* (fly) larvae live in rotting wood, they feed not on the wood but on moulds growing upon it. Again, Cleveland (8) has demonstrated that certain white ants are always associated with internal protozoan symbionts which enable cellulose to be digested by them. Escherich (9) has drawn attention to the presence of a yeast symbiont in the alimentary canal of the Anobiid beetle, *Anobium paniceum*. It is possible that, as Baumberger (3) and Chapman (6) have suggested, so-called wood-eating insects live on micro-organisms, the wood serving merely as a suitable substratum on which these feed and develop. If this be true for *Lyctus* then this insect will thrive only in timber which is in a suitable condition (possibly of moisture content) for the growth of the particular micro-organism with which it is associated. The recent work of Buchner (4) [1] has shown that the association of wood-boring insects with fungi may be far more general than has hitherto been imagined. The results of his researches indicate how important it is to ascertain whether any symbiotic relationship exists between fungi and wood-destroying beetles of the families Lyctidae and Anobiidae.

It is significant that a fungus of some species, alive or dead, has been obtained from a series of *Lyctus*-attacked timber specimens examined by the mycology section of the Forest Products Research Laboratory. A particular fungus, identified by Mr. Cartwright of this laboratory as coming fairly near *Phomopsis*, was isolated at an interval of a year by Mr. Day of the Imperial Forestry Institute and by Mr. Nutman of this laboratory. It is not yet clear whether this fungus can always be associated with *Lyctus*, but its appearance at such a long interval from quite different samples of *Lyctus*-infested timber suggests that this might be so.

The whole question of the relationship of wood-boring insects in general to the timber they attack, to the presence of fungus in the timber, and to the

[1] See review on p. 130.

occurrence of organisms within the body of the insect, requires investigation and forms part of the work of the entomology and mycology sections of this laboratory. The few facts set forth in the preceding pages indicate what such relationships may be. They are of the utmost importance for determining the conditions in timber which render it liable to attack, whether by *Lyctus*, *Anobium*, *Xestobium*, or other wood-destroying insects. With such information available, preventive instead of merely remedial measures will be the more easily devised for the control of these insects which cause such damage to timber in store and in structures in this and other countries.

ACKNOWLEDGEMENTS.

I am indebted to Mr. R. S. Pearson, C.I.E., F.L.S., Director of the Forest Products Research Laboratory, for granting permission to publish this article embodying results obtained from the work of the entomology section of the laboratory. I also wish to thank Dr. J. W. Munro for his advice and encouragement throughout the progress of the investigation.

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ON THE RELATIONSHIP BETWEEN VESSEL SIZE AND *LYCTUS* ATTACK IN TIMBER

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IT is coming to be realized that there exists a very close connexion between vessel size and the attacks of *Lyctus*, but as yet no authoritative statement seems to have been made on the subject. That the insect cannot deposit eggs in a cavity whose diameter is less than that of the eggs must appear to be axiomatic; the investigation described in this article was undertaken in order that a basis might be given for a definite statement. A more general account of the conditions governing *Lyctus* attack, by Dr. Fisher, will be found on p. 40 of this Journal.

MATERIAL.

The material examined was all from the collection of the Imperial Forestry Institute, Oxford. Every specimen that had been attacked was taken from the collection, and a fairly representative number selected for examination. Samples were taken of British timbers that are known to be attacked. In addition to these, for purposes of comparison, several woods with small pores were examined.

A list of species examined is given at the end of the article; the 108 specimens represent at least 71 species [1] of 32 genera.

Microscope slides of each sample were taken from the collection.

APPARATUS.

A simple device was adopted to facilitate the measurement of an adequate number of vessels; this was so efficient that it has been thought worth while recording.

The microscope was placed on a box about a foot high, and the tube arranged horizontally. Over the eye-piece a right-angled prism was fitted. A light-screen was erected so that the projected image could be clearly seen without using a dark room. A 'Pointolite' was used to give illumination.

A stage micrometer was placed on the stage of the microscope, and the image traced on a sheet of paper. The paper was rotated through 90°, and the image again traced. In this way a scale was constructed with lines representing distances of 10μ and 100μ. At the same time, in order to ensure that the image was not distorted in any part of the field, the paper was placed on a sloping board fixed at right angles to the beam of light. (Under the high power 10μ was magnified to about 1 cm., and it was found that with further magnification accurate measurement to less than 1μ would be quite easy.)

[1] In some cases only the generic name was known.

When a transverse section of a wood was placed under the microscope, and the image projected on to the scale, it was possible to read directly both the radial and tangential diameters of the vessels with very great speed and accuracy.

Two advantages were obtained:

(1) A number of vessels could be conveniently examined without moving the slide, and, as will readily appear, manipulation of the scale is simpler and steadier than that of the slide.

(2) All measurements were read directly in μ, so that no conversion was needed.

METHOD.

The number of slides examined was 108, and these were all from different specimens of wood. On each slide representative numbers of vessels, usually about fifty, were examined, and the radial and tangential diameters were recorded. In the ring-porous woods only the vessels of the spring wood were measured; in the diffuse-porous woods no such limitation was made, though it was not considered necessary to deal with vessels of less than 20–30μ.

The total number of measurements actually made was 12,512.

From these results the average vessel diameter of each slide, and thence of each genus, was calculated. It was found that, with few exceptions, the average vessel diameters of the species of a single genus were very similar.

Next, the average diameter of each vessel measured was obtained; this was accomplished by finding the mean of the radial and tangential diameters. The vessels were then grouped according to size, and the number of vessels occurring in each group was noted for each specimen. Since, as stated above, related species agreed so well, and as a greater number of measurements should give better results, the numbers of vessels between given limits were noted for each genus.

In order to make possible a comparison of genera, these figures were converted to percentages of the measurements made for the respective genera. Table 1 is an example of this treatment. A similar table was constructed for each genus examined.

TABLE 1

Genus: *Canarium*. (Number of vessels measured= 147.)

Vessel size (in μ) .	61–80	81–100	101–20	121–40	141–60	161–80	181–200	201–20
No. of vessels . .	2	4	27	48	40	22	3	1
Percentage of vessels .	1·4	2·7	18·4	32·6	27	15	2	0·7

The results collected in these tables were then plotted in a graph (Plate II, fig. 1). The horizontal axis represents the range of vessel size, and the figures were obtained from the top line in Table 1; the vertical axis represents the percentage of vessels of each size, and the figures were obtained from the bottom line in Table 1.

It will be observed that the curves are separated into five sets. The separa-

tion is simply to avoid the confusion that follows the plotting of all the curves to the same axes, and is without further significance.

The presentation of the results in a form more readily appreciable was attempted in the production of the graph shown in Plate II, fig. 2. Here the woods are arranged according to the position of the maxima in fig. 1. The exact position of the maximum frequency is in each case indicated by the centre of the black disk, whilst the length of the curve indicates the range of vessel size.

Finally, an abundance of information regarding the size reached by the eggs of *Lyctus* was provided by Dr. Fisher, who also supplied a series of twenty eggs of *L. brunneus* which were measured. It was found that in the case of this species the average diameter of eggs in the widest part was 150μ and the minimum diameter in the widest part was 137μ. Therefore the '*Lyctus* lines' were added to each graph. The line XX is in each case at 137μ, and indicates the minimum diameter as mentioned above. The line YY is at 150μ, showing the average diameter.

DISCUSSION.

In recent years much work has been done on the subject of the variation of certain structural features in various parts of trees. Perhaps fibre lengths and ray volumes have received most attention. One point noticeable in every case is that the variation within the individual may be considerable; it may be almost as great as the total variation for the species. The measurements made during this investigation tend to prove that these results may be extended to include the size of pores, for in several cases (e.g. *Albizzia*, *Bombax*, *Fraxinus*) single specimens showed very great variation. Beyond this reference little can be said in the present case, since the age and condition of growth of most specimens were beyond determination. In view of this variation, however, it is clearly the maximum vessel size that will act as a limiting factor in the attacks of *Lyctus* and not the average vessel size. For this reason the graphs were constructed.

From the graphs several points will be apparent.

Firstly, the shape of the curves is obviously of but one basal type—the normal distribution curve, and any differences are merely of degree.[1] The curves to the left are much taller than those to the right, whilst the latter have a greater spread. This is due to the fact that the curves to the left have a much less range, often less than 0–100μ (a range of less than 100μ), whilst *Bombax* ranges from about 150–400μ (a range of 250μ). When the 100 per cent. of vessels is spread over such a wide range, the curve must be expected to be

[1] The omission of all vessels less than about 20–30μ naturally affects the curves of several small-pored woods (e.g. *Populus*, *Tilia*, *Salix*). Fig. 2, Plate I, shows this point by the fact that in such cases the black disk is not central. Comparison of the maxima of these graphs and the average vessel sizes revealed expected discrepancies; for, whilst the calculated average must be greatly influenced by any selection in measurement (e.g. omission of very small vessels) the maximum of the graph is influenced to a less degree, and is therefore likely to be nearer the actual value.

lower. It is noticeable that the woods with larger pores have also a wider range of pore size.

Secondly, the curve of *Symphonia globulifera* is exceptional in having two maxima, one, to the right, being shallower than the other. This is due to the fact that here only two specimens were examined, and these had very different ranges of vessel size. The reason for this is not known. It may be that one of the specimens was wrongly named. The curve was included in spite of this doubt, because it illustrated admirably the possible diagnostic value of variations in vessel size, and is suggestive of avenues of further investigation, when, in the future, more is known of the variation possible within a genus. After the curves were completed the writer was informed that 'Waika', or 'Waika Chewstick' is the common name for *S. globulifera*. In the light of this knowledge, the distribution curves of the three specimens assume additional interest, for this third sample has the majority of its vessels of a size intermediate between those of the other two.

Thirdly, the relationship between the curves and the '*Lyctus* lines' is of great importance.

Since in any wood whose vessel distribution lies wholly to the left of the lines the insect would find oviposition impossible, it is reasonable to assume that these woods are immune to attack, for the insect seems always to deposit its eggs in pores (see Dr. Fisher's article). Certainly there is no authentic report of their infection in this country.

The greatest interest attaches itself to those curves cut by the *Lyctus* lines. They represent the majority of the specimens examined. In some, most of the curve is to the right of the lines; where the maximum of the curve (or the black disk of fig. 2, Plate II) is so placed it means that attack is very probable, though the approach of the maximum to the 'lines' renders attack less likely. In this connexion the case of *Ulmus* may be quoted; reference to the plate will reveal the position of the maximum; the wood is attacked, but to a less degree than *Quercus* or *Fraxinus*.

Here let us note that though the line xx, representing the minimum diameter recorded for the *Lyctus* egg, must be near the *critical* point, it is in the region of the line yy that most of the eggs fall, so that it is the proximity of the black disk to this region that is of the greatest practical importance.

In several cases the maxima of the curves fall to the left of the line. It follows that there is less likelihood of these woods suffering, and that the probability of attack should be proportional to the areas between the curve and the axis, as separated by the *Lyctus* lines.

It may be of interest to note that the maximum size reached by any vessel measured during this investigation was 520μ; and that two vessels having a radial diameter of this dimension were found in *Castanea sativa*, Mill.

ACKNOWLEDGEMENTS.

In conclusion the writer wishes to record thanks to Mr. R. S. Pearson, C.I.E., Director, Forest Products Research Laboratory, for permission to publish this

article; he desires also to express his indebtedness to Mr. L. Chalk, M.A., Imperial Forestry Institute, Oxford, and to his colleagues of the Wood Structure Section, Forest Products Research Laboratory, for helpful suggestions, information, and advice.

SUMMARY.

(1) The study of the relationship between vessel size and attack by *Lyctus* leads to the conclusion that vessel size is a limiting factor in *Lyctus* attacks. Where the largest vessels of a given wood are less in diameter than the smallest *Lyctus* egg, the woods are immune. As the percentage of vessels of greater diameter than the insect's egg increases, the probability of attack becomes greater.

(2) In this study vessels of 108 specimens were measured; these were representative of 71 species of widely distributed genera.

(3) A simple device is described for the measurement of microscopic objects. It consisted in the projection of an image on to a scale reading directly in parts of a millimetre.

LIST OF SPECIES EXAMINED

(Genera with species found in Dr. Fisher's investigations to be attacked by *Lyctus* are indicated by asterisks.)

Acacia.
A. ferruginea, DC. (two specimens).
Acer (sycamore).
A. pseudoplatanus, L.
A. saccharinum, Wangenh.
A. saccharum, Marsh.
**Adenanthera.*
A. pavonina, L.
Aesculus (horse chestnut).
A. hippocastanum, L.
**Ailanthus.*
A. glandulosa, Desf.
A. sp.
**Albizzia.*
A. Brownii, Walp. (two specimens).
A. fastigiata, Oliver.
A. lucida, Benth.
A. odoratissima, Benth.
A. stipulata, Boiv.
A. sp. (five specimens).
Betula (birch).
B. alba, L.
B. nigra, L.
B. papyrifera, Marsh.
**Bombax.*
B. malabaricum, DC. (two specimens).
B. sp.
**Canarium.*
C. euphyllum, Kurz.
C. mauritianum, Blume.
C. schweinfurthii, Engl.
**Castanea* (chestnut).
C. sativa, Mill. (two specimens).
**Dalbergia* (rosewood).
D. cana, R. Grah.
D. melanoxylon, Guill. and Perr.
D. Oliveri, Gamble.
D. sissoo, Roxb.
D. sp. (five specimens).
**Diplotropis.*
D. sp. (two specimens).
**Entandrophragma.*
E. utile, Sprague (two specimens).
E. sp. (three specimens).
Fagus (beech).
F. ferruginea, Ait.
F. sylvatica, L.
**Fraxinus* (ash).
F. americana, L.
F. Bungeana, A. DC.
F. nigra, Marsh.
F. sp. (three specimens).
**Juglans* (walnut).
J. cinerea, L. (two specimens).

Juglans (cont.)
J. nigra, L.
J. regia, L.
Ochroma (balsa).
O. sp. (two specimens).
*Parinarium.
P. excelsum, Sabine.
P. Holstii, Engl.
*Polyscias.
P. kikuyuensis.
Populus (poplar).
P. alba, L.
P. deltoides, Marsh.
P. nigra, L.
P. tremuloides, Michx.
P. sp.
Prunus (cherry).
P. cerasus, L.
P. serotina, Ehrh.
P. spinosa, L.
*Pterocarpus.
P. indicus, Willd.
P. macrocarpus, Kurz.
P. osum, Craib.
P. tinctorius, Welw.
Pyrus (apple).
P. malus, L.
Quercus (oak).
Q. spp.
Salix (willow).
S. nigra, Marsh.
S. tetrasperma, Roxb.
S. sp.
Swietenia (mahogany).
S. macrophylla, King.
S. mahagoni, Jacq. (two specimens).
*Symphonia.
S. globulifera, L.
*Tabebuia.
T. sp.
*Terminalia.
T. bellerica, Roxb.
T. bialata, Steud.
T. superba, Engl. (three specimens).
T. sp. (two specimens).
*Tetrameles.
T. nudiflora, R. Br.
Tilia (lime).
T. americana, L.
T. europea, L.
T. mandshurica, Rupr.
Ulmus (elm).
U. americana, L.
U. campestris, L. (two specimens).
U. minor, Mill.
U. montana, With. (two specimens).
U. racemosa, D. Thomas.
*'Waika Chewstick.'

EXPLANATION OF PLATE II

Fig. 1. Normal distribution curves showing by genera the distribution of vessel size. XX is the minimum diameter recorded for the egg of *L. brunneus* (measured in the widest part). YY is the average diameter of the egg of *L. brunneus*.

Fig. 2. Woods arranged according to the vessel diameter which is most frequent in each genus (as revealed by fig. 1). Length of curves indicates ranges of vessel size: centres of black disks indicate positions of the maximum frequencies. XX and YY as in fig. 1.

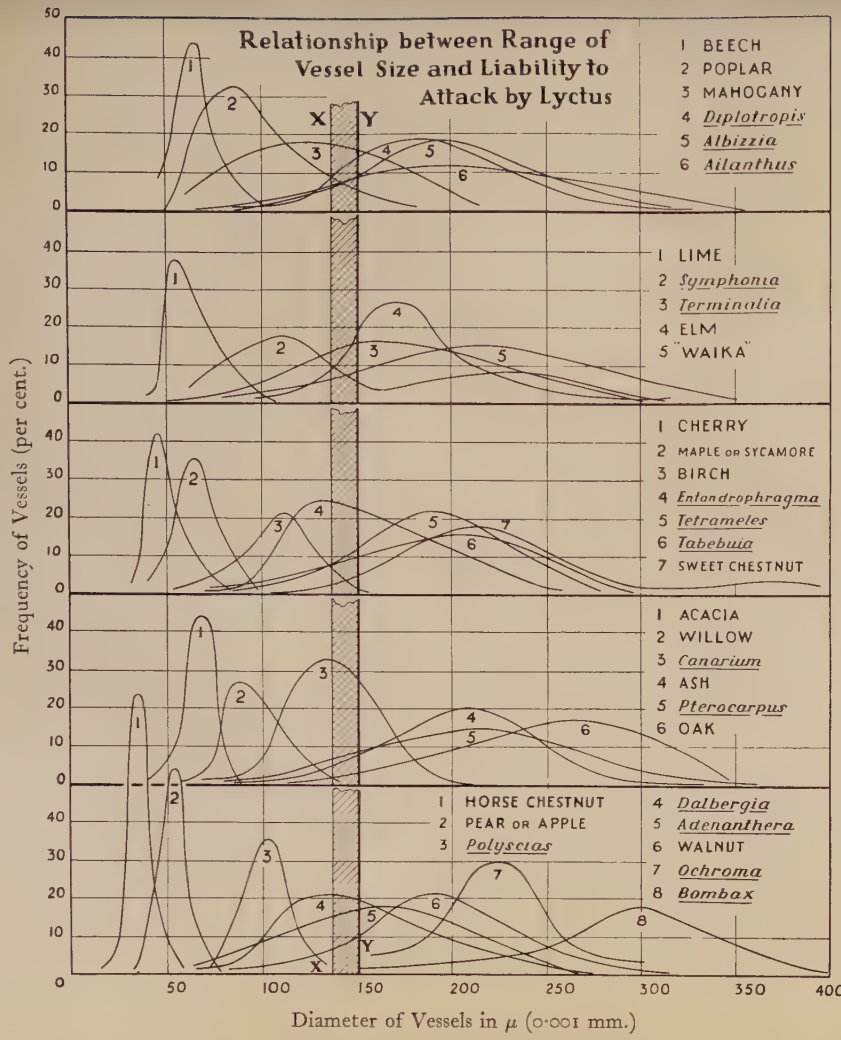

FIG. 1

PLATE II

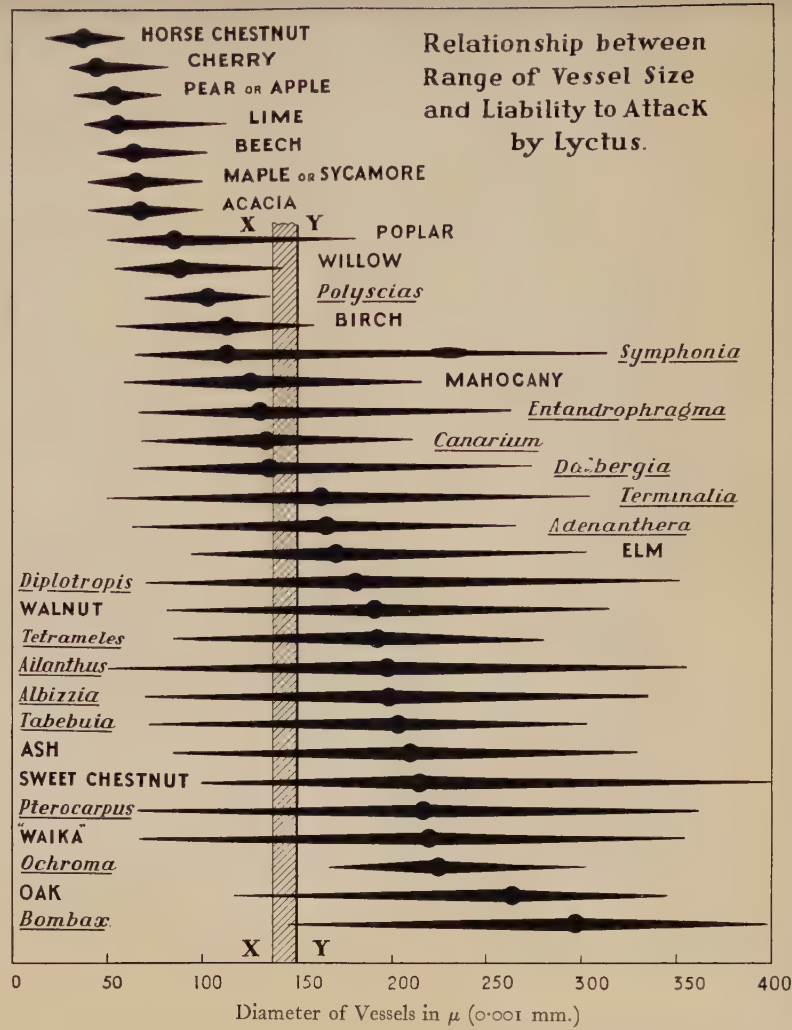

FIG. 2

THE RELATION OF THE ELM BARK-BEETLES TO THEIR HOST TREES [1]

BY RONALD C. FISHER

INTRODUCTORY.

THE following notes are based on the results of a series of experiments which were conducted during the year October 1923–October 1924 at Ravenscourt Park, Hammersmith, and other L.C.C. parks in the neighbourhood of London. Owing to taking up a new appointment in 1925 the writer has been unable to continue this work. Within such a short period it was not possible to obtain as complete a record of observations and results as could be desired, but, supplemented with notes on life-history studies of the elm bark-beetles made in the London district from 1921–4, it is thought that such results as have been obtained may prove of interest and importance.

ECONOMIC IMPORTANCE OF THE ELM BARK-BEETLES.

The elm bark-beetles, *Scolytus destructor*, Ol., the larger, and *S. multistriatus*, Marsh., the smaller species, occur commonly in the southern counties of England. Normally they breed in felled logs, but at times may be very injurious to standing trees. They may attack trees of all ages, but the nature of the attack, its distribution, and the species concerned vary with the age and size of the trees. Since *S. multistriatus* prefers to cut its egg-tunnels on the more slender branches and on those with thin bark, it is found, when present on large trees, most commonly in the crown; *S. destructor*, on the other hand, prefers large branches with thick coarse bark, and may be present on the main stem. In young trees both species may frequently be found together on the main stem only, the twigs and branches being too thin and slender even for *S. multistriatus*. In still younger trees in which the diameter of the stem is less than 4 inches the smaller species alone may occur, particularly if there is more suitable breeding material for the large elm bark-beetle in the immediate neighbourhood.

In the past, attention has been drawn from time to time to the damage caused to elms in the London parks, and various accounts of the depredations of these beetles are to be found in entomological literature. During the period 1921–3 the elm bark-beetles again proved troublesome, and helped to cause the death of several fine elms in different parts of London.

CONDITION OF TREES ATTACKED.

Much discussion has taken place in the literature as to whether these insects attack healthy trees. Denson (2) states that they are not found on strong vigorous trees, while Guérin-Ménéville (4) is convinced that healthy trees are subject to attack. Chapman (1) states that he never found any trace of

[1] Forming part of a study of the 'Structure and Biology of *Scolytus destructor*, Ol.', made whilst a holder of a Ministry of Agriculture and Fisheries Research Scholarship, 1922–5.

S. destructor on healthy growing trees. Working with *S. multistriatus* Macdougall (6) concluded that this species also did not attack sound trees. Conclusive information on this matter is, however, lacking. An outbreak of elm bark-beetle in Ravenscourt Park in 1924 afforded an excellent opportunity for further investigation of this question, when, through the courtesy of the superintendent of parks for the London County Council, facilities were obtained for carrying out a series of experiments. Observations made in the Royal Botanic Gardens, Kew, and in Richmond Park, indicated that apparently *S. destructor* does not attack perfectly healthy, strong, and vigorously growing trees for the purpose of egg-laying. If, however, from any cause whatever, the vitality of the trees be reduced they seem to become liable to attack. Many apparently healthy trees were attacked in the spring of 1922: it will be recalled that a severe drought occurred during the summer of 1921, the result of which became evident the following year when elms suffered badly from the elm bark-beetles. Evidently the drought had brought about in the trees conditions suitable for attack. A study of these conditions and their causes would lead to a better understanding and facilitate anticipation of outbreaks not only of the elm bark-beetles, but of other injurious insects associated with trees apparently in excellent condition, or in a weakened and dying state. With this end in view the following experiments were carried out in spring and summer 1924 at Ravenscourt Park.

EXPERIMENTAL WORK.

The trees used in the experiments varied from 6 to 12 feet in height, and from 2 to 4 inches in diameter at breast height. The species were *Ulmus campestris*, *U. montana* var. *pendula* and var. *fastigiata*. Three specimens of *U. stricta* included in the experimental plot were the survivors of a group of thirty young elms which had been 'heeled-in' temporarily in the nursery at Ravenscourt Park, prior to transplanting in spring 1923 in their final position to form a new avenue. This group of young elms was severely attacked by bark-beetle whilst awaiting transplanting: only three trees remained alive. Transplanting had been delayed, and it appeared probable that this had to some extent caused the beetle attack.

Experiment I.

To ascertain whether trees with ample root system are equally subject to attack by elm bark-beetles as trees with poor or deficient root system.

Group A. Controls. Three trees with good fibrous roots (fig. 1) transplanted 11th January 1924.

Group B. Three trees with heavily pruned roots: fibrous roots removed (fig. 2).

Tree B_1. Pruned 22nd January, transplanted 4th March.
" B_2. " " " 17th January.
" B_3. " " " 25th January.

Groups D, F, H } Three trees in each group: also root-pruned and transplanted at intervals.

Until transplanted in their final position in the experimental plot all trees were kept in another part of the nursery, 'heeled-in' with their roots well covered with soil.

Results of Experiment.

By April it was quite evident as to which trees had been root-pruned. Spring 1924 was a backward season and all trees were slow in opening their buds. As the weeks passed, however, while the buds of the unpruned trees slowly but steadily opened, on only one of the three pruned trees of Group B did the buds open at all.

Tree B_2. (*U. montana* var. *pendula*). Fair crop of leaves by mid-July.

Trees B_1 and B_3. (*U. campestris* and *U. montana* var. *fastigiata*). No leaves right throughout summer.

Groups D, F, H } Poor foliage: check to growth apparent in all trees except two. Four trees entirely devoid of leaves.

Quite apart from beetle attack it was clearly demonstrated that var. *pendula* withstood the check inflicted by root-pruning more successfully than did the other two species; *U. campestris* was the most sensitive. No indication of beetles attacking any of the trees was seen in this experiment until 11th July, when several adults of *S. multistriatus* were found commencing egg tunnels on trees B_1 and B_3. A tunnel was also found on D_3, a tree which, although root-pruned, yet carried good foliage. No beetles were found on any other tree which had received a check in this manner. On the control trees, Group A, with sound roots, no signs of egg-tunnels were seen. Here and there on other control trees there were indications of tunnels having been attempted but soon abandoned. Such tunnels took the form of short galleries cut at nodes on the main stem of the young trees and were probably feeding-tunnels (see p. 60). It has been stated many times in the literature that frequently an attack is checked by an outflow of sap at the invaded points. Undoubtedly this occurs when the tree attacked is sufficiently healthy and vigorous. An examination of all trees in October 1924 showed that those with sound roots had resisted attack and were in a healthy condition. On 14th July it was noticed that one of the three trees which had survived the attack of 1923 had been attacked again. A tunnel 2 inches in length was exposed and contained a female of *S. multistriatus* egg-laying. Young larvae were present, the first-laid eggs in this tunnel having hatched. Other egg-tunnels were present on this tree, which was the most sickly looking of the trio; the other two, which did not appear to be attacked, were growing vigorously and evidently had recovered from the attack of the previous year.

The results of this experiment, such as they are, indicate clearly that, in the first place, a healthy, vigorously growing tree is not attacked by the elm bark-beetles. Secondly, if a tree is subjected to a check in its growth, for example by too severe pruning at the time of transplanting, it is then liable to attack. If, however, the check is too severe the tree may be in too sickly a state for the

insect. Only in this way can one account for beetles not attacking all the root-pruned trees. A possible explanation is that in the case of a healthy tree the sap content of the bark and living wood is too high, while in the case of the root-pruned but unattacked trees with very poor or no foliage it is too low for the beetles to be attracted to them and for their development. Some intermediate condition of sap content suitable for the insect would seem to be necessary. Further evidence in support of this theory will be brought forward when the results of Experiment II are discussed.

Experiment II.

To ascertain the relation between different times of transplanting elms and their liability to attack by bark-beetles.

Group I. Three trees transplanted 3rd January 1924.
„ J. „ „ 17th April 1924.
„ K. „ „ 15th May 1924.
„ L. Two trees „ beginning of June 1924.

Controls. Batch of Cornish elms used to form the new avenue at Ravenscourt Park to replace old trees felled in 1923. The roots of these elms were in excellent condition and had an abundance of fibrous roots: trees planted in their final position in the avenue on 22nd February 1924. Each tree planted in a specially prepared pit with soil and manure, so that all trees were given every chance of growing vigorously.

Results of Experiment II.

On the majority of the trees the buds opened and the foliage developed while they were 'heeled-in' in the nursery. Transplanting, however, checked and in some cases stopped further development, withering of the leaves following.

Condition of Trees in July 1924.

Group I. All healthy; trees growing vigorously, not attacked by bark-beetles.

Group J.
J_1. Foliage poor; leaves withering; attacked by *S. multistriatus*; several egg-tunnels found.
J_2. Foliage very fair; not attacked.
J_3. Foliage excellent, apparently normal.

Group K.
K_1. Foliage poor; a few egg-tunnels of *S. multistriatus*.
K_2. Foliage very fair; not attacked.
K_3. Foliage very poor; badly attacked; more tunnels of *S. multistriatus* on this tree than on any other in the experiment.

Group L.
L_1. Devoid of leaves; very slight attack.
L_2. Devoid of leaves; very slight attack.
(Both trees apparently dead when examined in October; fungus was present on them also.)

Controls. Avenue trees—all in excellent condition; foliage abundant; no attack by beetles.

The above results indicate that delay in transplanting elms, even although their roots are not root-pruned and are normal, is quite sufficient to render them liable to attack. Further, if in addition to delayed transplanting the roots of trees are too severely pruned, the chances of attack by bark-beetles are greatly increased. In order to obviate any liability to such an attack it is essential that all transplanting should be completed by the middle of March and, if possible, by the end of February. In this way only will it be possible to be reasonably certain that, if the trees are otherwise healthy and vigorous, risk of attack will be reduced to a minimum.

DISCUSSION OF RESULTS OF EXPERIMENTS.

While beetles were not found attacking root-pruned trees until 11th July, the first signs of attack on trees whose transplanting had been delayed was seen on 26th June. Apparently these were in a more suitable condition for attack and were more attractive to the insect, since both sets of trees were growing side by side and were equally exposed to beetles. In all cases it was noticed that those trees which were most severely attacked neither possessed healthy normal foliage nor were entirely devoid of leaves. As has already been indicated in Experiment I, it seems probable that an intermediate condition of foliage can be correlated with liability to attack. The condition of the foliage is governed by root pressure and by the sap content of the tree as a whole. Evidently the bark-beetle is able to gauge in some manner, possibly by its antennae or other sensory organs, the moisture (sap) content in a given tree or part of a tree, and can thus distinguish between trees too dry, too moist, or in an intermediate state suitable for egg-laying and the development of larvae of a new generation. Experimental work has offered proof of this. Comparisons of the moisture content of different trees were made in the following simple manner: By means of a Pressler's increment borer cylinders of wood were taken from healthy unattacked trees, from trees which had been root-pruned, and from trees with normal roots but which had been delayed in transplanting. The percentage loss, after heating, of each cylinder of wood was obtained and in this way a rough comparison made between the different trees. Since all the trees were approximately the same age and were growing in the same plot such a comparison seemed justifiable. The following is a summary of the results obtained:

I. *Control Trees.*

Roots untouched; foliage normal; all trees planted on 3rd January 1924 and examined on 4th July 1924.

Tree A_1 (*U. montana* var. *pendula*), moisture content: sample $a = 33{\cdot}2$ per cent.; sample $b = 32{\cdot}3$ per cent.

Tree C_1 (*U. campestris*), moisture content $= 31{\cdot}0$ per cent.

Tree G_2 (var *pendula*), moisture content: sample $a = 32{\cdot}7$ per cent.; sample $b = 31{\cdot}7$ per cent.

Average moisture content of group $= 32{\cdot}18$ per cent.

II. *Trees Delayed in Planting.*

Roots untouched; *U. campestris* only used.

Tree L_2, planted early June; examined 4th July 1924; moisture content: sample *a* = 29·7 per cent.; sample *b* = 29·7 per cent. Tree devoid of leaves; one beetle found tunnelling on 1st July 1924.

The following trees, when examined on 1st July 1924, all showed poor, withering foliage and were attacked by bark-beetles:

Tree J_1, planted 17th April 1924, moisture content = 31·1 per cent.

Tree J_2, planted 17th April 1924, moisture content = 32·6 per cent.

Tree K_3, planted 15th May 1924, moisture content: sample *a* = 33·3 per cent.; sample *b* = 34·6 per cent.

Average moisture content of group = 31·8 per cent.

III. *Root-pruned Trees.*

Foliage entirely absent; trees examined 4th July 1924.

Tree B_1 (*U. campestris*), planted 4th March 1924, moisture content = 26·7 per cent.; slightly attacked.

Tree B_3 (*U. fastigiata*), planted 19th January 1924, moisture content = 30·4 per cent.; slightly attacked. This species withstood pruning well, hence high figures.

Tree D_1 (*U. campestris*), planted 17th January 1924, moisture content = 30·4 per cent.; unattacked.

Tree F_1 (*U. campestris*), planted 21st January 1924, moisture content = 27·1 per cent.; unattacked.

Average moisture content of group = 28·6 per cent.

It is noticeable that where trees appeared healthy and were growing vigorously the percentage of moisture present was highest and beetles were absent. Where root-pruned trees bore no foliage the moisture percentage was less and again beetles were absent or present only in very small numbers. On the other hand, beetles were found attacking trees which had suffered a check through delay in transplanting, resulting in a slight decrease in moisture content of the stem, although the roots had been functioning for a short period. In the case of trees transplanted late in the season their roots had been acting more efficiently than those which had been severely root-pruned. In the first case the sap rose and buds opened, while in the second this was checked at the beginning of the growing season by severe root-pruning. Trees delayed in planting received a check later, but their sap content in July was higher than that of the root-pruned trees, yet not so high as that of control trees unpruned and in good health. It is thus of interest to recall that beetles were found on trees which had been delayed in transplanting earlier than on trees which had been root-pruned. These results form further evidence of a definite relation between deficiency of moisture content of a tree and its suitability for attack by the elm bark-beetles.

Under natural conditions in the field, factors are present and circumstances may prevail which can bring about results exactly similar to those obtained in the experiments just described. For example, mention has already been made of the increase in numbers of bark-beetles following the serious drought of 1921.

PROGRESS OF ATTACK ON OLD ELMS.

The results of the experiments show that in the case of young elms only weakly, unhealthy individuals are liable to attack by the elm bark-beetles. When such young trees are attacked the presence of the beetles is easily detected since they attack the main stem, the twigs and branches as a rule being too slender to afford sufficient room for the cutting of egg-tunnels. The same factors determining the liability to attack are applicable to old as well as to young trees—unhealthy trees are attacked while healthy ones escape. In the case of old trees, however, the attack usually commences in the crown of the tree and spreads gradually downwards. Observations have repeatedly shown this progress of attack; it is of interest to notice that even although the bark-beetles gradually spread downwards from year to year, in many instances they were seen to confine their tunnels to one side of the tree. Such a tree (fig. 3) was found at Marble Hill Park, Twickenham. The top was dead, but the lower third of the tree was still alive and bore living branches and leaves. In autumn 1923, larvae of *S. destructor* were found in abundance on the north side from ground level up to a height of approximately 7 feet. Higher up the tree the attack seemed to be past—many exit holes being observed. Beetles emerged from the lower part during spring and summer 1924, and these cut new tunnels low down on the main stem. They confined themselves chiefly to the north side but spread to a slight extent round the tree.

As in the instance of young trees, so in old; when too dry, almost dead, beetles will not attack them. The insects cut their egg-tunnels not in the dry, dead parts of a tree but in the living, though unhealthy branches. Whatever be the cause, the presence of bark-beetles on an elm indicates that the tree is not in full vigour. When one tree is attacked and its neighbour unattacked the attacked tree lacks something—a normal moisture content—which the healthy tree possesses. It may be that constitutionally the one tree is not so sound as the other and is thus predisposed to attack; consequently, when some unfavourable conditions prevail—for example a severe drought or when the tree is getting past maturity—it is so reduced in vigour as to be at once in a favourable condition for the bark-beetles which establish themselves usually first of all in the crown. Escherich (3) states that the beetles attack sound limbs in the crown of trees, but in the light of our experiments it appears certain that such limbs are not healthy but are deficient in moisture content, and at the time of first attack do not visibly differ from their healthy neighbours. Once a tree has begun to decline in health and does not recover its former vitality the beetles will continue to breed in it, gradually extending their distribution on the tree. Fungus may and usually does follow the attack of the beetle, killing the branches after the insect has passed on to fresher ones. The elm bark-beetles are not found in trees or branches infested with fungus as are *Ernoporus fagi* or *Dryocoetes autographus*, which live in fungus-infested beech and spruce respectively. In the case of these bark-beetles the wood in which they breed is in an advanced stage of fungal decay. This is not the case with the elm bark-beetles: the wood in which they feed and develop is not

severely attacked by fungus. It is, however, probable that the death of many elms is caused by the action of fungi for the development of which the way has been prepared by the insects.

FEEDING OF NEWLY EMERGED BEETLES ON HEALTHY TREES.

Although *S. destructor* and *S. multistriatus* do not attack healthy trees for egg-laying purposes, young immature adults cut feeding galleries at the nodes and in the axils of twigs of perfectly healthy trees prior to egg-laying. According to Escherich (3), quoting Röhrl, the effects of the feeding of such immature beetles on young elm twigs are harmful, the death of the young twigs resulting and serious damage being caused to underwood management. The writer's observations, however, indicate that little damage is done. Rarely, ringing of the twigs occurs, but most commonly the feeding tunnels do not extend right round the twig: a callus forms which rapidly heals over the wound and the health of the branch apparently does not suffer. The writer was struck with the rapidity with which such wounds heal over: even where several beetles had been feeding at the same point, so long as the twig was not completely ringed, little harm resulted.

SUMMARY.

(1) A series of experiments was conducted to ascertain the relation between the health of elm trees and their liability to attack by the elm bark-beetles *S. destructor*, Ol., and *S. multistriatus*, Marsh.

(2) The results show that trees with poor or deficient root systems are more liable to attack than trees with ample root systems.

(3) Delay in transplanting young elms in early spring has been found to render them open to attack by the bark-beetles.

(4) A close relationship exists between the health and vigour of the tree and its liability to attack.

(5) Evidence is cited which indicates a relationship between the moisture content of a tree, or part of a tree, and its power of resistance to the beetles. A certain deficiency in moisture content renders elms liable to attack and suitable for the development of bark-beetles.

(6) The death or decline of an elm tree is not caused by elm bark-beetle attack alone, but in all probability by fungal attack following the insects and completing the damage begun by them.

(7) Newly emerged, immature bark-beetles may feed at the nodes of small branches on a healthy tree without impairing its health.

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The writer wishes to thank Dr. J. W. Munro, formerly entomologist to the Forestry Commission, for his advice and encouragement during the progress of this investigation, which was carried out in his laboratory. Thanks are also due to the Parks Superintendent of the London County Council for so kindly providing facilities and trees for experiments at Ravenscourt Park.

Fig. 3. Elm in Marble Hill Park, Twickenham, attacked by *S. destructor*. Note stag-headed appearance, tree dying back from crown.

Fig. 1. Normal unpruned root system of a control tree

Fig. 2. Root-system of tree *B*, after severe pruning

PLATE III

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EXPLANATION OF PLATE III

Fig. 1. Normal unpruned root system of a control tree.

Fig. 2. Root system of Tree B_1—after severe pruning.

Fig. 3. Elm in Marble Hill Park, Twickenham, attacked by *S. destructor*. Note stag-headed appearance, tree dying back from crown.

RESEARCH IN WOOD STRUCTURE

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INTRODUCTION.

IN the opening volume of *Forestry* the Assistant Director, Major Oliphant, gave a short account of the organization of the Forest Products Research Laboratory and of the field of investigation covered by the different sections into which the work naturally falls. The object of the present paper is not only to present an account of some of the main features of research work on wood structure, and to indicate what is being done by the members of the Laboratory's staff working at Oxford in relation to the work of the Laboratory as a whole, but also to show that much of this work is closely bound up with that of the Imperial Forestry Institute and is of direct interest to those who are engaged in the practice of forestry.

As is already known, forest products research deals with all those problems which centre round the economic use of wood in those numberless purposes to which it has been put by mankind, and in which difficulties are frequently encountered owing to its many widely varying qualities. Forestry research, on the other hand, centres round the growing of the raw material, timber; its problems are in the main biological, since they deal with the reaction of a living crop, trees, to such factors as climate, soil, and exposure to fungal and insect attack. There is, however, a region where these two lines of research either overlap or are complementary to one another, and it is for this reason that the Forest Products Research Laboratory and the Imperial Forestry Institute have both felt the need of working in close co-operation.

In order to give an unrestricted view of the relation of wood structure to the problems encountered in forestry and in forest products research, no hard-and-fast line will be drawn in what follows between the actual work being done at Oxford by the Forest Products Research Laboratory and that by the Imperial Forestry Institute, as the nature of the work of these two organizations is sufficiently clear from the preceding paragraph.

IDENTIFICATION OF WOOD.

One of the most important aspects of research in wood structure is connected with identification. Of the innumerable number of woody plants which man uses only a relatively small proportion is in general commercial use. The number, which is steadily growing as newer timbers and their qualities become known and recognized, is determined by such factors as the quantity available, accessibility, and the uses for which the timber is suitable.

The first essential in forest products research work is the correct naming of the material handled. This is only possible where wood specimens and botani-

cal material have been obtained from the same tree, so that anatomical features of the wood can be added to the botanical description. In the past, confusion has frequently arisen because the identification of woods with botanical species have been based on such insecure foundations as a native name which frequently covers more than one species. To establish a collection of correctly identified woods the Imperial Forestry Institute have developed a scheme whereby the Dominions and Colonies send home samples of wood from trees of which material has been preserved for botanical identification. Concurrently, information is collected in the country of origin to supplement present information on quantity available, accessibility, and price; this should be of considerable value for the newer and less well-known woods.

The collection of identified wood specimens housed at the Imperial Forestry Institute has now increased to some three thousand specimens, and fresh material is continually being added. This number falls short of the number of timbers which eventually will come to be of commercial importance either from the point of view of value or of quantity, and much work remains to be done before a really representative collection of the timbers of the world will be available for study.

Microscope sections prepared from wood samples so collected provide the basis for the identification of unknown woods. Before, however, such a collection can be used satisfactorily for this purpose it has been found that considerable experience is necessary in recognizing structural differences between woods and in the preparation of keys as an aid to identification.

The chief structural characteristics of wood which have been found of most value in identification include the presence or absence and the size and distribution of vessels, wood parenchyma, and resin canals; the size and structure of the medullary rays; and the size, shape, and number of pits and other sculpturings on the cell walls. Keys based on such characters have been published at various times for the identification of the commoner or the more important timbers of different countries. Among these may be mentioned those of Hartig for European, Record for North American, and Brown for Indian timbers. Such keys have their limitations, and at present the identification of a specimen of an unknown wood is not generally practicable without access to a collection of authenticated wood specimens and prepared microscope sections supplemented, when this is possible, by reference to such works as Gamble on Indian timbers, Moll and Janssonius on the Javanese woods, and Record and Moll on those of the tropics of the New World.

To those who are acquainted with the difficulties which are met with in the identification of woods, there is no need to point out that identification from wood samples cannot be made with the same precision as from botanical material, due to the frequent absence of clear-cut specific or even generic differences. While, however, a precise identification is often impossible it is generally possible to obtain an identification sufficiently close for commercial purposes. For instance, among the hundred odd species of the genus *Pinus*, a specimen of pine wood can be classed as belonging to one of three groups of

which the soft pines and the pitch pines are the two most important: with additional information as to the country of origin it is generally possible to narrow down the identification to a small group of species marketed under one commercial name. Much the same applies to oaks and eucalypts.

The African mahoganies are an example where it is sometimes impossible to decide on structure alone to which genus a wood belongs. The wood structure of the Meliaceae or mahogany family is very uniform, and though individual species may be distinctive enough there is, as far as wood structure is concerned, no clear-cut distinction between species and genera. In cases such as these part of the difficulty of identification lies in the circumstance that the exploitation of the timbers is farther advanced than the botanical survey, with the result that there is no botanical check on the commercial or vernacular names.

It will not be out of place to mention at this point a few of the advantages that the existence of a collection of woods of the type described has been found to have in the commercial world. During the handling of the collection much information about the different woods has already accumulated, and with the added information derived from the microscopic structure it is possible to give suggestions as to new or substitute woods for different purposes either in the interest of economy or to take the place of those whose supply is dwindling. From a consideration of a series of photomicrographs of wood sections, the Research Station at Dehra Dun found it possible to select from the four hundred or so commercial woods of India about six which could be used in place of boxwood (*Buxus*). It was also found at Dehra Dun that wood structure was of considerable assistance in wood preservation, in that the most suitable method of treatment for any particular timber could be determined with considerable accuracy from an examination of photomicrographs of the wood structure.

Correct identification is of considerable value from a somewhat different aspect. Vernacular names are frequently local, and the same timber may come on the market under several names all of which are not equally well known. Correct identification will prevent confusion arising among both buyers and sellers, who may not always realize that they are dealing with the same timber. Again, fresh woods are frequently placed on the market under names the same as or similar to those of well-known kinds, and satin walnut is an instance of our old friend clad in borrowed plumes.

Quite recently the identification of charcoals has become an interesting development of the study of wood structure. Although considerable volume shrinkage occurs during its conversion into charcoal the minute structure of wood is hardly altered, and with careful manipulation charcoals can be identified as readily as ordinary wood. Identifications of archaeological charcoals possess at times considerable interest for the evidence they give as to whether certain trees in England are true natives or have been introduced.

In addition to its value from the commerical point of view, wood structure possesses considerable interest from the systematic standpoint. The classifica-

tion of flowering plants is based on various morphological features connected principally with the floral structures. The division of the plant kingdom into a number of groups or natural orders by such means becomes intelligible in the light of evolution.

Up to the present time it has been chiefly in the conifers that attention has been paid to wood structure in connexion with systematy and evolution. On *a priori* grounds Jeffrey has laid down an evolutionary sequence for certain types of wood structure, notably in connexion with the distribution of medullary-ray tissue and of wood parenchyma, which has contributed valuable evidence to the vexed question as to the direction in which evolutionary sequence in this group should be read.

In regard to dicotyledonous or broad-leaved trees, on the other hand, comparatively little work has been done in this respect, a neglect that is somewhat surprising considering the amount of interest which has been shown in wood structure during recent years. To help to fill this gap some preliminary work is being done in co-operation with the Imperial Forestry Institute in drawing up summaries of the structural features shown by the woods of the different families. Several instances have come to light where an examination of wood structure has been of value in confirming or disproving the position assigned to tree species whose place in the systematic classification has been doubtful.

VARIABILITY IN WOOD STRUCTURE.

In addition to the problems connected with the identification of woods there are two other aspects of the study of wood structure which are at least as important and have a particular interest to those who are interested in forestry in Great Britain.

When the wood of any particular species is closely studied a considerable range in structural variation is disclosed; not only does the width of the annual rings often vary enormously from year to year, but other structural features show an equally wide range related no doubt to the conditions to which the tree was exposed during its growth. To mention a few such characters the volume occupied by the medullary rays is very much less in suppressed trees than in dominant trees; in English oak there is a large variation in the proportion of fibrous tissue; under sub-alpine conditions woods which are normally diffuse-porous tend to become ring-porous; the average thickness of the cell wall does not remain constant within a species; and finally structure varies somewhat with position in the tree.

It is the variation in such characters as those mentioned in the last paragraph which accounts, no doubt, for the large range in strength values which nearly all species of wood exhibit, for the preferences shown in the trade for wood from certain localities, and for the prejudices against wood of apparently similar type from other localities. The discrimination which is exercised in the selection of willow for making cricket bats, ash for tennis rackets and other sports requisites, and oak for cabinet work is well known to many.

In all questions of the utilization of wood it is necessary to determine the

basis of these preferences and prejudices, in order to obtain the best market for the quality of timber which can be grown in the country, and to supply the quality most suited to the particular needs of the customer. At the present moment there is no certain knowledge of the extent of structural variation which is normal for trees native to or grown in Great Britain, nor any certainty of what effects are due to climate, silvicultural methods, and local conditions, what to the occurrence of sub-species and local races, or hybridization. To obtain information on this subject an investigation has been started on the effect of these factors on some of the more important timber trees in Great Britain, and of the relation of structural variation with the more important economic properties such as strength, seasoning, and wood-working qualities.

The outcome of this investigation will be valuable in two distinct aspects. Not only will the timber-user be helped in the choice of the most suitable material for his purpose, but also, with the co-operation of the forester, it should be possible to lay down what cultural variety of a species, what soils, and what silvicultural methods should be chosen to produce the quality of timber which will yield the greatest profit to the grower and be most suitable to the consumer and the development of a market.

To illustrate the kind of value that this research is likely to have, two concrete examples will be given.

In the structural examination of the material used in the investigation of the strength properties of timbers grown in Great Britain, the relation between strength and the proportion of fibre was confirmed in oak, and from the appearance of smooth transverse sections it is possible for any one who is familiar with the structural characters to arrange a series of samples very closely in the order of their relative strengths.

The next illustration emphasizes an aspect which is of interest to the forester. Recently a series of tests was carried out by the Laboratory at Princes Risborough on the relative strength of pit-props of home-grown Douglas fir for comparison with other timbers. It has been established by work at the Laboratory that for many woods maximum strength is definitely correlated with a definite ring width.

In this country it would seem that the growth of Douglas fir is more rapid in early life than in its native home, and produces a timber of a ring-width which is in excess of the known optimum for maximum strength. From a study of the range of conditions under which Douglas fir grows in its own country it should be possible by selecting suitable localities and by adapting present silvicultural methods to reduce the rate of growth of Douglas fir sufficiently to bring the timber within the ring-width class correlated with maximum strength.

Besides its relation to mechanical properties and to questions of utilization wood structure and its variation is being studied also for its influence on the seasoning qualities of wood. The structural features that are generally likely to be of importance in seasoning are usually of a macroscopic nature and

do not require the same close analysis as the work in connexion with the mechanical properties.

The number and size of the medullary rays in wood has a considerable effect on the occurrence of checking during the seasoning progress. This is very noticeable in oak, where in some seasoning experiments it was shown that timber with a larger proportion of the big medullary rays is much more prone to check than timber where this proportion is lower. These large rays form planes of weakness along which splitting takes place to relieve the stresses set up by the shrinkage, due to loss of moisture, during the course of drying.

The presence of knots and the occurrence of irregularities in the direction of the grain increase the liability of wood to warp during seasoning. This is very patent in the case of elm; the excessive warping shown by this wood, however, may be due to other causes such as the relation of shrinkage, on moisture loss, to local variations in structure and density. It will not be possible to say more on this particular subject, however, until the relation of the shrinkage of this wood to moisture content has been studied in greater detail.

STRUCTURE OF CELL WALL.

In addition to the subjects of identification and of variability of structure there is a third aspect, relating to the finer structure of the cell wall of woody tissues, on which a few words are required in order to conclude this account of the research being carried out on wood structure.

For many years distinguished botanists have studied plant membranes, including those of woody tissues, from structural, physiological, and developmental aspects with what assistance was forthcoming from chemistry and physics. In view, however, of all the recent work on physical chemistry and the property of colloids, and of the standardization of the methods of the chemical analysis of wood, much of this work on plant membranes will have to be reviewed in order to make it available for use in connexion with the problems which are met with in forest products research.

In recognition of the importance of this work a start has been made on making a preliminary survey of this field, but although it will not be possible to gauge the value of this survey until it has been completed there is no doubt that problems connected, for instance, with wood preservation will be made clearer by a proper understanding of the structure and of the physical and chemical properties of the cell wall and of the part it is capable of playing in the adsorption of preservatives. As it is, the close study of the cell wall has yielded information of value. Slip planes can be demonstrated in the cell walls of wood that has been strained beyond the elastic limit. These slip planes, which are no doubt similar in character to those occurring in metals, become very numerous in the region of failure, and are recognized by their peculiar optical properties and by the alteration of the normal staining reactions of the cell wall. Splits and cracks are at times very prominent features in the cell walls, especially of conifers; very often such cracks are caused by severe seasoning treatment, but so far no close study has been made of the factors which

govern their formation nor of their possible value as an aid in estimating the effect of various kiln treatments on the quality of timber.

CONCLUSION.

The relation of structure to other physical properties of wood has been purposely omitted from this discussion of research on wood structure. The most important of these relations is that of wood to moisture, and although structure plays an important part in the seasoning, shrinking, swelling, and warping of wood it was judged that this aspect of wood structure is best dealt with as subsidiary to the whole question of the relation of wood to moisture. It is hoped, however, that it will be possible at some later date to deal with the moisture relationships of wood in all its aspects and to describe the work that has already been done on this subject.

In concluding, it can be safely stated that the structure of wood, in some form or other, enters into nearly all questions of utilization, and that its study forms a necessary foundation for many of the investigations undertaken in forest products research.

I wish to thank the Director of the Forest Products Research Laboratory for permission to publish, and acknowledgements are due both to him and my colleagues for information given during the preparation of this article.

THEORETICAL CALCULATION OF THE PRESSURE DISTRIBUTION ON THE BASAL SECTION OF A TREE

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THE suggestion has been put forward that internal stresses are built up in the trunk during the growth of a tree. When the tissue of the current year's growth is being laid down it is plastic and cannot take an active share in supporting the dead weight of the tree until lignification is complete. As successive growth rings are laid down there will be a continuously increasing load on the earlier formed rings which will produce a pressure gradient rising from zero at the periphery to a maximum at the centre. If this pressure gradient should become large, owing to conditions of growth, there is the possibility that the additional stresses due to wind action might be sufficient to cause incipient failures in the stem giving rise to a brash condition of the wood.

Some observations on an elm log which was being sawn up at the Forest Products Research Laboratory brought this suggestion to mind. The sawn ends of a perfectly flat 3-inch plank which had been sawn through the centre of a 10-foot elm log were observed to be curved and not straight. This curvature suggested that the central portion of the log might have expanded longitudinally on sawing from the tree due to the release of internal stresses in the trunk.

In order to obtain information as to whether the pressure gradient that would result from the suggestion in the opening paragraph would be sufficiently great to cause the amount of curvature noted at the ends of the elm plank, the following series of calculations were made. The data on which they are based were derived from yield tables for spruce (1), Douglas fir (2), oak (3), and redwood (4).

From the yield tables for these trees the area of the basal section and the volume of the average tree was obtained after successive decades. The volume was corrected by adding a percentage to include that of the branches and bark. The weight of the tree after each decade was obtained by multiplying this corrected volume by the density of the green wood, using data given by Newlin and Wilson (5); see Table 1. In Table 2 are given, by way of example, the figures which were thus obtained for the increasing weight of Douglas fir with age.

From the figures in Table 1 it is seen that for trees of the ages given, the mean pressure on the basal section is a little greater than one atmosphere for conifers, while in the oak, the only hardwood for which calculations were made, the average pressure is about three atmospheres.

As mentioned previously, it is unlikely that the pressure distribution will be uniform, since the outer annual ring is laid down in a plastic condition while the centre regions are under the load of the superincumbent mass of the tree.

Assuming that wood is not plastic once it has become lignified, the pressure distribution on the basal section can be calculated quite simply from the data derived from the yield tables (see Table 2 for those for Douglas fir). At the end of each decade the increment during that decade is divided by the area that the basal section has attained at the end of the period. This figure is the average pressure added over the whole basal section due to the growth of the last ten years. By a process of summation the total pressure over the areas of the basal section covered by the growth of the successive decades is obtained, which gives the pressure gradient.

The results so obtained are summarized in Table 3, which gives the pressure distribution that is to be expected over the basal section of the oldest trees of the species investigated for which data were available. In the conifers the pressure rises gradually from the outside to an average of 40 lb. per sq. in. near the centre, the actual amount depending on the age and the species. In the hardwood, oak, the pressure rises to about three times this value. The pressure at the centre might rise considerably higher in trees where the ratio of the area of the basal section to the weight is smaller, but it is doubtful if it would reach a value much greater than 300 lb. per sq. in.

In the actual tree the pressure gradient due to the successive growth increments may not rise to the full theoretical amount. In the green state wood possesses considerable plasticity, and it is not inconceivable that this gradient may be considerably reduced owing to this circumstance.

If reference is made to Table 4, which gives the modulus of elasticity and the stress at the elastic limit for the trees investigated, it is seen that pressures of the order calculated are well within the elastic limit. The strains that they would produce would normally be undetectable, amounting as they do to less than 0·01 per cent. of the length, and would not materially add to the strains set up by wind action, especially as these are confined to the peripheral regions of the trunk. Thus this pressure gradient is unlikely to act as a contributory cause in the production of brashness in wood.

The pressure distribution given in Table 3 will be found only in well-grown trees with a vertical stem and a well-balanced crown. If, however, a tree has a well-developed branch on one side or if it grows at the side of a ravine, the pressures will be far greater than those for an ideally grown tree, and in addition they will not be concentrically distributed. In extreme cases they will range from compression on one side to tension on the other side of the tree, but even here, if the necessary corrections are made for the inclination of the stem or the leverage of a large branch as the case might be, the pressure distribution due to the cause under consideration would still be detectable.

An interesting case is the distribution of pressure over a section near the base of a horizontal branch. In a beam projecting horizontally from a wall, as a cantilever, the upper surface is under maximum tension, the under surface is under maximum compression, while towards the centre the stresses diminish to zero.

If the hypothesis is true that wood is plastic when being formed and only

takes its share in mechanical support after lignification, it follows, on reasoning out the distribution of stresses during the gradual growth of the branch, that the distribution of stresses is the reverse to that of a cantilever beam and ranges from zero at the upper and lower surfaces to a region of maximum tension and maximum compression in a plane passing horizontally through the centre which consequently would be a plane of maximum shear. However, such a condition cannot normally occur, as the growth of branches is generally eccentric, being either hypotrophic or epitrophic, with the result that the regions of maximum compression and tension will be separated by an amount depending on the eccentricity of the pith or centre of growth.

In the near future it is intended to design and carry out field experiments sufficiently delicate to detect a pressure gradient of the order demanded by the considerations relating to growth increment discussed in the paper. If these are successful it is hoped that considerable light will be thrown on such problems as centre round eccentricity of growth and the occurrence of stresses in the standing tree.

SUMMARY.

Following some observations during the sawing up of an elm log data were brought forward to show that the pressure gradient set up in a tree due to its continuously increasing weight with growth is unlikely to have any measurable effect on the longitudinal dimensions of the timber when the strains produced by this cause are released by sawing.

Further, the pressure gradient due to this cause is not sufficiently great to contribute to those incipient failures in the lower and central portions of the stems of certain trees which may cause brashness.

In conclusion, I wish to thank Mr. Pearson, C.I.E., F.L.S., Director of the Forest Products Research Laboratory, for permission to publish, Mr. Chaplin for helpful criticism, Dr. Steven for supplying me with information on yield tables, and Mr. Koehler of the Forest Products Laboratory, Madison, U.S.A., who stimulated my interest in this subject.

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TABLE 1. *Some data on which calculations were based*

	Correction for weight of branches and bark. Per cent.	*Density of green wood. lb. per cub. ft.*	*Age. Years.*	*Mean pressure over basal section. lb. per sq. inch.*
Spruce . .	+20	35	120	17
Douglas fir . .	+20	38	140	14
Oak . . .	+50	67	150	42
Redwood . .	+25	45	60	16

TABLE 2. *Douglas fir. Weight and area of basal section of an average tree with increasing age*

Age.	*Basal area. sq. in.*	*Green weight. lb.*	*Age.*	*Basal area. sq. in.*	*Green weight. lb.*
20	19	88	90	300	3,674
30	37	235	100	357	4,491
40	71	649	110	418	5,422
50	113	1,225	120	475	6,376
60	158	1,835	130	525	7,231
70	203	2,400	140	570	7,980
80	248	2,973			

TABLE. 3. *Pressure distribution over basal section (lb. per sq. in.) for an average tree of Douglas fir* 140 *years, redwood* 100 *years, oak* 150 *years, and spruce* 120 *years old*

Portion of basal section between rings.	*Douglas fir.*	*Redwood.*	*Oak.*	*Spruce.*
0–20 . . .	40·1	30·2	120	50·2
20–30 . . .	35·5	22·3	114	42·2
30–40 . . .	31·5	18·6	103	34·9
40–50 . . .	25·8	15·3	90	29·2
50–60 . . .	20·7	11·9	77	23·8
60–70 . . .	16·8	9·0	66	18·8
70–80 . . .	14·0	6·3	56	13·9
80–90 . . .	11·7	4·0	48	9·6
90–100 . . .	9·4	2·0	40	5·9
100–110 . . .	7·1	—	32	3·1
110–120 . . .	4·9	—	25	1·1
120–130 . . .	2·9	—	18	—
130–140 . . .	1·3	—	12	—
140–150 . . .	—	—	5	—

TABLE 4. *Compression at elastic limit and under a load of* 100 *lb. per sq. in.*

Wood.	*Modulus of elasticity.*[1] *lb. sq. inch.*	*Fibre stress*[1] *at elastic limit. lb. sq. inch.*	*Compression at elastic limit. Per cent.*	*Compression for* 100 *lb. per sq. inch. Per cent.*
White spruce	968,000	3,160	0·33	0·01
Douglas fir	1,242,000	3,570	0·29	0·008
Redwood	1,024,000	4,530	0·44	0·01
White oak	1,137,000	4,320	0·38	0·009

[1] Data taken from Record (6).

METHODS OF PLANTATION AND NURSERY COSTING

BY R. L. ROBINSON

IT is not intended in the following remarks to discuss the place of a costing system in forestry operations beyond stating that within the limits set by the handling of living material (where cheapness is not everything) the procedure described has proved useful to the Forestry Commission. It is based on the principles that costs shall be quickly available to the man directly responsible for the expenditure involved, and that they shall be elaborated from the bottom (starting with labour in the forest) upwards.

Bearing in mind that the Commission's operations have been on an expanding scale which entails the commencement of new afforestation units and the formation of new nurseries annually, it will be realized that the expenditure of any one year is incurred in respect of a number of operations which are in various stages of completion. A large-scale plantation may not be satisfactorily established for some years after the first planting; a nursery is certainly not fully productive until it has been some years under cultivation. It is only by analysis of expenditure in relation to work done that a clear view may be obtained of what is happening.

In order to analyse expenditure it is necessary to have definite heads to which it may be placed. The following are the 'standard heads' in use by the Commission so far as planting and nursery operations are concerned.

Head.	*Description.*
E. 7 (d).	Preparation of ground.
„ (e) (1).	Planting or sowing: plants or seed.
„ „ (2).	Planting or sowing: labour, &c.
„ (f) (1).	Beating up: plants or seed.
„ „ (2).	„ labour, &c.
„ (g) (1).	Weeding.
E. 7. (g) (2).	Cleaning.
„ (h).	Drainage: new works.
„ (k).	„ upkeep.
„ (m).	Fencing: new works.
„ (p).	„ upkeep.
„ (r).	Forest protection.

Nurseries.

E. 7 (b).	Nursery: new works.
„ (e) (1).	Nursery upkeep: plants.
„ „ (2).	„ „ preparation of beds and sowing seed.
„ „ (3).	„ „ weeding beds.
„ „ (4).	„ „ protection of beds.
„ „ (5).	„ „ lifting, grading, packing, heeling in, and transport of seedlings to station or lines.
„ „ (6).	„ „ preparation of lines and lining out.
„ „ (7).	„ „ weeding lines.
„ „ (8).	„ „ lifting, grading, packing, heeling in, and transport of transplants to station or home forest.
„ „ (9).	„ „ general.
„ (s).	Seed collection, extraction, and distribution.

PROCEDURE.

Particulars of the men employed are recorded daily by the foreman in the *time book* which he carries with him for the purpose. The unit for recording time is a half-day. In the form below, the six vertical columns under each name are reserved for the respective days of the week.

Time Book.

Week ending.....

Compartment.	*Nature of work.*	*Names.*											
		A. Workman.						*A. N. Other.*					
P. 28	Prep. ground	1	1	½									
	Drainage, &c.			½	1	1	1				1		

These particulars are summarized by the forester in the *summary time sheet* from which is prepared the *pay list.*

Summary Time Sheet (Day Work)

Forest..... Week ending.....19....

Name of workman.	*Compartment, &c.*	*Nature of work.*	*Total days worked.*	*Daily rate of pay.*	*Amount due and remarks.*
				s. d.	*s. d.*	*£ s. d.*
A Workman	P. 28	Prep. ground	2½	6 0	15 0	
		Drainage	3½	6 0	21 0	
					——	1 16 0
A. N. Other	P. 28	Drainage	1	6 0	6 0	
					——	6 0

Pay List.

.....Pay List. Period ending.....

Name.	*Days.*	*Rate.*	*Gross amount.*	*Signature in acknowledgement of receipt.*
		s. d.	*£ s. d.*	
A. Workman	6	6 0	1 16 0	
A. N. Other	1	6 0	6 0	

The forester measures up the work done during the pay period (usually a fortnight) and makes out the *progress report.* He is then in possession of the unit cost of labour employed on his various operations. The total expenditure shown in the progress report will, of course, agree with the total of the pay list—items of expenditure which are not costed being included (generally under 'Part III. Other') in order to provide this useful check.

PROGRESS REPORT.

Progress Report and Analysis of Pay Lists

Forest..... ..... weeks to .....

Nature of work.	*Unit.*	*Current.....*			*Total quantity to date.*
		Quantity.	*Cost of labour.*	*Cost per unit.*	
			Part I. Plantation.		
			Part II. Nursery.		
			Part III. Other.		

The time sheet, pay list, and progress report are then forwarded to the district officer to check, to note for action, and to submit to the divisional officer. The unit labour costs are therefore reviewed in rapid succession by two forest officers. A monthly summary of progress reports is made for the assistant commissioner on a *costing return* (see page 76).

Apart from wages there may have been other expenses in connexion with the forest, e.g. plants and fencing material. From the divisional office a statement or *cash account* goes monthly to head-quarters of all payments and receipts. That statement is supported by vouchers (pay list, paid bills, &c.), on the back of each of which is placed an indication of how the expenditure should be classified according to the standard heads of account. This is done with a rubber stamp in the following form:

Standard head No.	*Amount.*		
	£	*s.*	*d.*

A summary of the indications given on the vouchers to accompany the statement is made up on what is called a *classified abstract of payments.*

Classified Abstract of Payments for Month ended.....19....

Division..... Forest Unit .....

Standard head.		*In division.*	*At head-quarters.*	*Total for previous months.*	*Total to date.*	*Folio in head-quarters ledger.*	*Approved estimate.*
No.	*Description.*						

The classified abstract is cumulative. At the end of a Forest Year, therefore, the expenditure under each 'standard head of account' is easily ascertained.

COSTING RETURN ..... Division. ..... Forest. Month .....

Name of work.	Standard head.	Quantity of work done.		Cost of labour.		Unit.	Cost per unit.		Remarks.
		For month (to last pay day inclusive).	Total to end of previous month.	For month (to last pay day inclusive).	Total to end of previous month.		For month.	To end of previous month.	

PLANTATION COSTING.

The quantities of work done in a forest for the plantations of different years are reported annually either by standard heads or by groups of heads which compose a definite operation. The corresponding expenditure as shown in the classified abstract, when divided by the quantity of work done, gives the unit cost of the operation. It is thus relatively easy to get at the cost per acre of planting a newly planted area, provided that no advance work was done in former years, and that no advance work has been done in respect of future years. Such occurrences are noted in reports of work done so that due allowance may be made. The easiest method of making allowance is to determine not the actual cost of planting but the rate of cost of planting. Thus 300 acres may have been prepared (Prep. Ground) at a cost of say £200 (13*s.* 4*d.* per acre), whereas only 200 acres were planted. It is legitimate to include in the rate of cost of planting the figure of 13*s.* 4*d.* against Prep. Ground. The form of the final rate of cost of planting is given below.

Rate of Cost of Planting

Operation.	*Cost per acre.*		
	£	*s.*	*d.*
Preparation of ground		13	4
Drainage		7	0
Fencing		16	1
Planting or sowing: plants or seeds .	2	3	8
,, ,, labour . . .	1	5	1
Weeding		8	3
Total . .	5	13	5

The prices of plants in the above table are put in at what are called 'standard prices', which apply equally to all plantations and are ascertained in the way described under Nursery Costing below.

The *cost of establishment* (i.e. the money expended per acre on a plantation up to the time it requires no more weeding) is more

difficult to determine and obviously cannot be finally determined for the individual plantation until that stage has actually been reached. For the whole of the operations, however, a *rate of cost* can be fairly easily found by adding together the costs for the year in question of plantations newly planted, those planted one year, those two years, &c. The example below illustrates the method.

Rate of Cost of Establishment

Operation.	*Cost per acre.*		
	£	*s.*	*d.*
Preparation of ground		13	4
Drainage		7	0
Fencing		16	1
Planting or sowing: plants or seed . .	2	3	8
,, ,, labour, &c. . .	1	5	1
Beating up: plants first year . . .		12	0
,, ,, second year . .		2	8
,, labour first year . . .		8	0
,, ,, second year . .		2	6
Weeding first year		8	3
,, second year		8	0
,, third year		7	6
Total . .	7	14	1

NURSERY COSTING.

There are certain difficulties in the way of determining the cost of producing nursery stock, arising out of the technical procedure adopted in Great Britain. The chief of these is that the output of any given year is not necessarily related to the expenditure of the year. There may be sent out from a nursery, for example, 100,000 two-year two-year transplants on which the expenditure was mainly incurred in previous years, or *per contra* nothing may be sent out, but considerable expenditure incurred on raising seedlings. The first tentative costings by the Forestry Commission were on the lines of following up, year by year, the expenditure incurred in producing plants from a given batch of seed. This was soon found to be impracticable owing to the fact that the plants at different stages became distributed over different parts of the same nursery, and even of different nurseries. Further, some of the plants were used at one age or stage, some at another. It was thus found almost impossible to keep track of the different batches.

The procedure which has finally been adopted is based on a similar conception to that adopted in the case of planting and establishment costs, namely, on *the rate of cost of production in any one year*. This principle in its application to nursery work requires some further explanation. The results which are obtained by expending money on a nursery during the course of a year are a series of changes which convert seed into one-year seedlings, one-year seedlings into two-year seedlings, two-year seedlings (if transplanted) into two-year one-year transplants, two-year one-year transplants into two-year two-year

transplants, and so on. The fact that certain of these plants are removed from the nursery for use is only incidental in the costing process.

If therefore we could determine the cost of producing each of these changes we should be in a position to ascertain the rate of cost for the year of producing plants which is composed of any given number of the changes. The necessary steps are outlined below.

Capital Expenditure. In the first place it is necessary to keep capital expenditure, such as the first costs of fencing, first breaking up of the ground, &c., separate, and to charge to the annual cost of operations only a proportion, which is fixed with reference to the special circumstances of the nursery.

Current Expenditure is summarized for the year from the 'Standard Heads' (see p. 73) into the following 'essential operations', i.e. operations which are necessary, under British practice, to produce the changes referred to above:

(a) *Seed Beds*

Preparation of beds and sowing . . .	E. 7 (c) (2)
Weeding	(c) (3)
Protection	(c) (4)
Lifting, grading, packing, &c.	(c) (5)

(b) *Transplant Lines*

Preparation of lines and lining out . . .	(c) (6)
Weeding	(c) (7)
Lifting, packing, &c.	(c) (8)

There is in addition general expenditure, E. 7 (c) (9), such as weeding paths, cost of manures, &c., which is applicable to the whole nursery and not necessarily to a part of it. This is allocated on a percentage basis to each of the 'essential operations'. Capital expenditure is dealt with in the same way.

Total Expenditure. All the direct expenditure incurred on the nursery during the year, as well as a given proportion of capital expenditure, has now been distributed over the essential operations. The next step is to divide the expenditure on each by the respective amount of work.

Quantities of Work Done. The annual return for each nursery shows the stocks of all categories of plants at the end of the year, and the area of ground occupied by each category. The returns also show by species the number of pounds of seed which have been sown during the year, the number of seedlings lifted, the number of transplants lined out, and the number lifted. Comparison of two consecutive returns, therefore, indicate quantitatively the 'changes' produced during a year and also the percentage of plants of different species which survive each change.

Unit Costs of Essential Operations. The unit cost (cost per 1,000) of certain of the essential operations can be obtained at once. For example, the cost of lifting transplants is known and number lifted. In other cases such as 'Preparation of beds and sowing', the unit cost is taken on an area basis (per 100 sq.

yds.), and the one-year seedlings of each species debited with their proportionate cost. Weeding is dealt with similarly. As regards seed beds it is assumed, as an approximation, that both one-year and two-year seed beds require the same amount of weeding, and that the unit area cost is consequently the same for both one-year and two-year seedlings. A similar assumption is made in the case of transplants. In the case of protection, which is not applicable to all species, a special note is made of those protected and the cost applied direct to them.

The following example illustrates the form in which the results emerge:

Operation.	*Unit.*	*Unit cost.*
		£
Preparation of beds and sowing .	100 sq. yds.	0·662
Weeding beds, &c. . . .	,,	1·728

The above data have next to be applied to each group of plants: for example, 20 lb. of Scots pine seed were sown in 600 sq. yds. of ground and produced 300,000 one-year seedlings. The total cost of the seedlings is made up of

	£	*s.*	*d.*
Cost of seed, 20 lb. @ say 10*s.* per lb.	10	0	0
600 sq. yds. prepared and sown @ £0·662 per 100 sq. yds.	3	19	5
600 sq. yds. weeded @ £1·728 per 100 sq. yds. . .	10	7	4
Total . .	24	6	9

and the cost per 1,000 is £24 6*s.* 9*d.* divided by 300, which is 1*s.* 7*d.* per 1,000. Again, 100,000 one-year Scots pine seedlings occupying 200 sq. yds. changed during the year into 75,000 two-year seedlings. The total cost of producing the change is

200 sq. yds. weeded at £1·728 per 100 sq. yds. = £3·456
and the cost per 1,000 two year is £3·456 ÷ 75 = 11*d.*

The rate of cost per 1,000 of two-year Scots pine seedlings is therefore the cost of producing $\frac{1{,}000 \times 100}{75}$ one-year seedlings, plus the cost of changing that number of seedlings into 1,000 two-year seedlings, i.e. 1*s.* 7*d.* $\times \frac{100}{75}$ + 11*d.* = 2*s.* 1*d.* + 11*d.* = 3*s.* The rate of cost of transplants is obtained in the same way.

While the whole costing procedure is not easy to explain concisely in a short article, it is found in practice that it is not expensive to work.

Intensive costing as described above is applied to some five or six large nurseries only, and from the data thus obtained (overhead charges having been added) a standard price list is drawn up yearly to cover all categories of plants. For the smaller nurseries alternative checks on costs are available. First, the unit costs as determined in the costed nurseries can be applied in order to determine whether the actual total expenditure was reasonable. Secondly,

by means of a simple trading account the general efficiency of the nursery can be ascertained.

The following statement illustrates in brief the form of the account :

Trading Account

	£		£
Valuation of stock at beginning of year	630	Value of plants, &c., removed during year	633
Expenditure during year	729	Valuation of stock at end of year	1,017
Gross profit	291	Gross loss	—
	1,650		1,650

CHESTNUT COPPICE IN SOUTH-EAST ENGLAND

BY W. L. TAYLOR

AS a silvicultural system that of coppice, or its alternative coppice-with-standards, has fallen upon evil days in Great Britain. For various reasons the types of produce from such areas have largely ceased to be valuable, or have been entirely superseded. The extensive coppice areas throughout the southern counties of England, which formerly were managed on appropriate rotations with such meticulous care by generations of foresters now gone, are now almost everywhere neglected and unproductive. The market for hazel and oak coppice can be said to have disappeared: hoop iron has to a great extent displaced the split hazel rods; cheaper imported tanning stuffs have destroyed the market for coppice oak-bark; charcoal-burning and wood-turning linger only in a very few places as local industries; and with the advent of iron in the hop-gardens the demand for hop-poles has dwindled to very small proportions. It was the necessity of providing hop-poles which led, during the last century, to the laying down of a considerable aggregate acreage of Spanish chestnut coppice in the vicinity of the hop-gardens of Kent, Sussex, Surrey, and part of Hampshire, and it is for the produce of such areas almost alone among the types of coppice surviving to-day that a new and remunerative market has sprung up in recent years.

Chestnut coppice is the source of supply of the raw material of the cleft-pale-fencing industry. The species utilized in this manufacture is the Spanish or sweet chestnut, *Castanea sativa*, Miller (syn. *Castanea vesca*, Gartner). It is not an indigenous tree in Great Britain, but is now generally held to have been introduced during the Roman occupation of this country.[1] Spanish chestnut succeeds admirably in high forest or under a system of coppice in suitable situations in England and parts of Scotland. It is much more tolerant of soil conditions if coppiced than if grown as a forest tree, under which circumstances a light soil is usually productive of serious defects in the timber, notably cup- or ring-shake. If coppiced, the species will flourish on a moderately wide range of soils given sufficient, but not excessive, moisture, and the average degree of summer heat with which southern England is favoured. Excellent coppice crops of Spanish chestnut are obtained on soils overlying the Greensands, Wealden clays, Hastings Beds (sands and clays), and the Bagshot, Barton, and Bracklesham sands and gravels of the Upper Eocene. As a coppice crop it can prove profitable even on the stiffer clays [2] to be met with over the geological formations mentioned, in circumstances in which the species would have little or no chance of attaining its normal development under high forest conditions. The tree has decided calcifuge characteristics,

[1] Elwes & Henry, *Trees of Great Britain and Ireland*, pp. 837–45.

[2] John Evelyn, *Silva*, p. 94.

and will not succeed even as coppice on soils derived from the chalk or limestone formations.

In the counties referred to, and in part of the Isle of Wight, suitable soils are readily to be found in association with a rainfall varying from 28 inches to 36 inches annually, and a sufficient summer heat. These localities thus offer what are believed to be optimum conditions for this particular form of silviculture in the British Islands. In the earlier plantations, with the production of long, straight hop-poles in view, plants were usually inserted at 5 feet or 6 feet apart, but the better to satisfy the requirements of the pale-fencing industry a slightly wider spacing is to be preferred. The coppice is cut on a rotation of from ten to fourteen years according to the rate of growth. Marketing is customarily effected by sale by auction on the ground, the season's *coupe* having been marked out previously into lots or 'cants' varying in size to suit the requirements of individual purchasers, many of whom are in a small way of business. Lots varying in extent from two to five acres are popular, and bidding is always on an acreage basis. Purchasers pay a deposit of 25 per cent. of the total purchase-money of their lot or lots, and agree to conform to the rather exacting conditions of sale necessary for the proper protection of the forest. The balance of the purchase-money is payable at an agreed date subsequent to the felling, but prior to the removal of the produce from the woods by the authorized routes. Felling and extraction are done at the expense of the purchasers, who are obliged to fell and convert the coppice in a proper and workmanlike manner, a very necessary condition, because unless the coppice is cut at the due season, and by experienced woodmen, the stools suffer deterioration to the detriment of the stocking and subsequent growth. Felling is carried out during the winter months, the poles being trimmed out, sorted, and stacked at the sides of the rides for conversion on the spot in spring and early summer. The lop and top is burned on the ground, care being taken to destroy none of the stools, or sometimes faggoted if a market for faggots still lingers in the locality. Care is taken not to leave the extraction of the poles too late in the season or injury will be done in course of the work to the new coppice shoots which appear in profusion on the bare stools quite early in spring. The trimmed poles are roughly peeled by slicing off the bark with a draw-knife but not shaved clean. They are then cross-cut into lengths or 'bats' of from 2 feet to 6 feet long, and cleft by hand into pales roughly triangular in section with an approximate girth of 4½ to 5 inches. The cleft pales are bundled at once and the bundles tied with tightly drawn wire bands, an operation which combines to prevent warping and to straighten out natural bends in individual pales. The bundles are then set aside for seasoning, and while they remain in the woods piles of these bundles are usually protected from the sun by a light covering of the refuse (bark and chips) to prevent the pales splitting. The foregoing operations are all carried out in the woods at piecework rates, the bundles of pales being transported to the manufacturer's yards during the summer for making up into the chestnut-pale fencing which has become so widely known.

The Census of Production, 1924, gives the quantity of Spanish chestnut produced in Great Britain for that year as follows:

	Timber of sawmill size.		*Pit-prop material.*		*Firewood.*		*Other wood.*		*Total.*	
Country.	*Quantity.*	*Value.*	*Quantity.*	*Value.*	*Quantity.*	*Value.*	*Quantity.*	*Value.*	*Quantity.*	*Value.*
	cub. ft.	£	*cub. ft.*	£	*cub. ft.*	£	*cub. ft.*	£	*cub. ft.*	£
England	404,590	18,002	63,433	1,156	209,725	3,232	798,924	19,674	1,476,672	42,064
Wales	3,341	237	—	—	10,949	96	—	—	14,290	333
Scotland	14,621	603	—	—	256	6	—	—	14,877	609
Great Britain	422,552	18,842	63,433	1,156	220,930	3,334	798,924	19,674	1,505,839	43,006

The category 'other wood' contains *inter alia* fencing material and hop-poles, and it is significant that the output of smaller produce is almost exactly twice as great as that of large-sized timber. The return also emphasizes the fact that the English counties have practically a monopoly of this branch of forestry, and in the case of the coppice industry this is overwhelmingly so in the south-eastern counties of England.

Well-grown Spanish chestnut coppice on a twelve years' rotation will realize up to £45 per acre at public auction, but to realize this price the area must be planted pure, fully stocked, and with the growth straight and even. Unfortunately, through neglect and indifferent management many of the existing chestnut-coppice areas are by no means fully stocked. There is also much of such coppice which has been grown in association with standards to the detriment of the coppice crop, and again, much has been deteriorated by the admixture of other species, but even in such cases returns of from £15 to £30 per acre on rotations averaging twelve years have been realized with satisfactory regularity during the past ten years. The demand for the material is keen and is in fact a growing one.

In the making of the fencing the total labour bill per acre of coppice dealt with amounts to £40.[1] On a twelve years' rotation this amount is approximately twice that spent in wages under the older system of dealing with coppice for the production of hoops and small produce, and the new system thus means the employment of more men. A block of one thousand acres of chestnut coppice worked on a twelve years' rotation (providing annual *coupes* of 83·3 acres) can on the foregoing basis be relied upon to provide the equivalent of full-time work for from thirty to thirty-three men. In its present state of organization, however, much of the work is regarded and treated as seasonal, and full-time occupation is not usually found to any extent outside the activities of the few more highly organized fencing companies. Notwithstanding local differences as to labour and organization, the fact that one thousand acres can in this way be made to provide in wages a sum sufficient

[1] *Rural Industries of England and Wales*, i, pp. 108–10.

to maintain thirty to thirty-three men throughout the year is an important one in the forest economics of the south of England.

The silviculture of the Spanish chestnut under the coppice system presents few difficulties. The species is readily raised from seed, and ripe seed is to be had locally in most seasons in the south of England in spite of climatic uncertainties. It is to be noted, however, that some authorities favour imported seed. Owing to early and strong root development seedlings should be transplanted at one year. They can be planted out from the nursery lines as one-year two-year transplants, if the ground is moderately clear, and cut over at the collar as soon as they are established. Tending is afterwards simple and the risks are few. Spring frost can do serious damage to seedlings and transplants in the nurseries, and to the first year's coppice shoots, while protection from ground game and roe deer is essential. Dangerous insects and fungoid pests are rarely encountered.

From small beginnings the pale-fencing industry has become firmly established in Kent, Surrey, and Sussex, and with a growing demand there seems to be no reason why the field should not be extended. Mention has been made of the suitable land for the growth of chestnut coppice in east and south Hampshire, and in part of the Isle of Wight, and satisfactory crops can also be raised on the Old Red Sandstone soils of Herefordshire. That there is room for enterprise in this direction is evident, because chestnut pales are even now being imported from France. English manufacturers claim that the imported material is inferior in texture and workmanship to the home-grown pales. Most of the chestnut coppice produced in this country is relatively slowly grown, and is in consequence harder, tougher, and more resistant to moisture, than the continental product.

Here we have a well-established forest industry in the south-eastern counties, an industry which evinces all the symptoms of moderate prosperity and which is the means of maintaining a highly satisfactory number of men per 1,000 acres devoted to the production of the raw material. In view of the extreme importance of fostering rural industries in Great Britain the raising of a suitable acreage of chestnut coppice is a matter of importance. The present imports indicate that the home-grown supply is not entirely equal to the demand, and with the possible further break-up of chestnut-coppice-producing estates in the next decade the devotion of further acreage to this branch of forestry is clearly indicated. Without more planting the sources of home supply are in danger of becoming restricted, and buyers in the south-eastern counties are each season casting their eyes farther afield in the hope of finding what they need. The whole question merits a place in forest policy, at least equal to the dimensions the industry has attained and its potentialities for adding permanently to the over-thin ranks of the rural workers.

A SEVENTY-YEAR-OLD PLANTATION ON PEAT

BY J. A. B. MACDONALD

SITUATION.

THE Loch Tulla district in which this plantation is situated is in Glenorchy and Inishail in the county of Argyll. It has a typical west of Scotland climate with a rainfall of approximately 95 inches per annum; it is surrounded by high hills and is fairly sheltered. The plantation is on the north-west side of the loch and occupies the wedge-shaped portion of land which lies between the highroad leading over Black Mount Forest to Glencoe, and the shore of the loch. The plantation extends along the roadside from Victoria Bridge in the extreme west, where the altitude is about 560 feet, to a point 1½ miles north-east with an elevation of 954 feet. Snow does not appear to lie for long below the 1,000-foot contour, and no damage which could be attributed to it was observed. Except for a rectangular portion near the eastern corner of the plantation, shown in an old map to have been left unplanted, the whole of the wedge-shaped area had originally been afforested, but about thirty-seven years ago a great stretch of the plantation bounded on the north-west and south-west by the Allt Bhreachnais stream, and on the south-east by the loch, was destroyed by fire and had not been replanted; the remaining area of woodland is about 310 acres. The most marked topographical feature of the area is the deep ravine through which the Allt Bhreachnais flows on entering the wood, before it turns at right angles towards the loch. Rising from the loch-side the slope is generally gentle, but there are several terraces, usually with deep peat, flanked by steeper banks of moraine. The ravine mentioned occupies a fault line between the granite on the north-west and the undifferentiated schists and moine rocks on the south-east. These rocks on the south-east side of the fault are covered by a considerable depth of drift, and morainic banks and knobbies are frequent; but above, that is on the north-west side of the fault, the glacial deposits thin out, and especially above the road the granite is frequently exposed. That the granite soils are much richer than those consisting of morainic matter appears to be certain.

PEAT AND VEGETATION TYPES.

Excepting the ravine sides and a few of the steeper slopes where the mineral soil is exposed, the whole plantation is on peat. In quality the peat varies throughout the area, there being every gradation between rich 'flush' peats and poor, haggy, *Scirpus/Calluna* areas. Practically the whole length of the strip bordering the road (i.e. farthest into the granite area) has a covering of peat of the better 'flush' type, while by the loch-side and on the meadowland near the Forest Lodge there is a border of fairly rich peat resting on alluvium. Between these two good areas, with the exception of several local flushes and the mineral soil patches, the peat types are bad, and tree growth consequently very poor; in fact large areas of the poorest types are practically treeless. Generally speaking, the peat is black and crumbly or at least dark and non-fibrous on the better types (e.g. flushes); on the deeper *Scirpus*-dominant areas it is light in

colour and very fibrous; and on the *Calluna/Scirpus* knobbies, where it is always thin and lies on heavily leached moraine, the peat is dark and extremely tough. Not far below the surface in the better types, what is clearly woodland peat is obtained with the soil-tester, and there appears to be little doubt that, until comparatively recent times, these areas were covered by native Scots pine. Occasionally moss-grown stumps of old pine trees are seen protruding through the surface in different parts of the plantation, and almost invariably an uprooted spruce reveals one or more of these old stumps quite near the present surface. Where the ground is well drained this underlying woodland peat is brown and crumbly in texture. It is found under the poorer surface types in a more compact, sodden state, but here it is at a much lower level. There seems to be little doubt that the trees had disappeared from these areas at a much earlier date than from the better-drained soils.

Although the plantation varies much throughout in the preponderance of the various species, in the density of the stand, and in the composition of the ground herbage, it was found that six main conditions occur within its boundaries; these, of course, merge gradually one into the other and all sorts of intermediate stages appear. It was possible also, by studying the unplanted ground above the road, to find indications as to what the vegetation types now inside the wood would have become had they not been planted. The information gathered is presented in tabular form below: column 1 shows the silvicultural conditions under which the herbage plants (in column 2) are found, and in column 3 the corresponding 'outside' or unplanted ground is noted:

Type No.	*Silvicultural conditions.*	*Herbage plants.*	*Corresponding ground outside plantation.*
1.	Pine, larch, or spruce forming canopy on mineral soil, or soil with not more than 9 inches of peaty humus. Well-drained banks, &c.	Under spruce only a sparse covering of mosses. Under larch and pine: *Vaccinium Myrtillus* / mosses, or tussocky *Molinia* / mosses (mostly *Hylocomium splendens*). Occasionally some *Calluna*.	Drier knobbie slopes with *Calluna / Erica cinerea / Blechnum* and occasional *Pteris*.
2.	Under spruce in canopy on rich, drained peat. Flush peat originally.	Directly under trees only scanty mosses, as: *Hypnum cupressiforme*, *Plagiothecium undulatum*, *Hylocomium loreum*, &c. Where more light: *Aira flexuosa / Molinia / Oxalis acetosella*, and more luxuriant moss growth.	Nothing well enough drained outside to compare with this. Probably the ground now under *Molinia/Juncus articulatus/Calluna* would be similar at time of planting.
3.	Less dense spruce, or pine, or gaps in spruce. Peat usually deep and fairly rich. Not so well drained as 2, and, in any case, drainage not functioning. Flush areas.	*Molinia* / rushes / grasses with *Hylocomium* and *Hypnum* moss species in the drier spots: *Sphagnum* species where wetter. *Alders* are frequent. *Eriophorum vaginatum*, *Calluna*, and *Vaccinium Myrtillus* occur occasionally.	*Molinia / Juncus articulatus / Calluna / Scirpus / Eriophorum vaginatum/Myrica gale*. A very mixed herbage and evidently deteriorating. No drainage.

Type No.	*Silvicultural conditions.*	*Herbage plants.*	*Corresponding ground outside plantation.*
4.	Open mixed conifers with some alder and birch on alluvial peat area by side of meadow and loch. Peat rich and deep, but drainage usually poor.	Grasses / rushes / *Molinia* / *Ranunculus* species, &c., *Polytrichum* and *Sphagnum* species; *Thuidium tamariscinum*, *Hylocomium*, and *Hypnum* mosses where ground drier.	Rush / grass / *Calluna* all occasional to locally abundant.
5.	Thinly stocked pine areas on peat. (Probably if planted with spruce this would have become as 3 or even as 2.)	Tussocky *Molinia* to *Molinia* / *Eriophorum vaginatum* / *Vaccinium Myrtillus*.	As 3 above.
6.	Practically treeless areas of very poor peat. Occasional stunted pines only found here.	*Calluna* / *Scirpus* / *Erica tetralix*, *Molinia* / *Narthecium ossifragum* / *Sphagnum* to *Scirpus* / *Rhacomitrium* / *Calluna* (on hag tops) or *Scirpus* / *Eriophorum vaginatum*. Where thin, as on poor knobbies, there is a *Calluna* / *Scirpus* vegetation.	As inside.

It is difficult to estimate the time taken for the succession from pine forest—with an undergrowth of sub-shrubs such as *Calluna* and *Vaccinium*, and the better quality mosses—to a poor *Scirpus*-dominant type of vegetation, but in the Loch Tulla neighbourhood every step in this succession can be traced with some degree of assurance. On the south side of the loch a large, if somewhat dwindling remnant of the old natural pine forest remains, and round its outskirts the trend of the vegetation succession and the development of poorer and poorer types of peat can be easily followed. As the old pines die, or are blown down, there are no young trees to replace them; deer are responsible for the fact that no seedlings grow much above the level of the herbage, because where small wire-netted enclosures have been erected here and there, there is a dense crop of young pines. The steps in the retrogression of natural woodland into moorland at Loch Tulla are similar to those recorded by different writers and may be summarized. The stumps and fallen trunks of the old trees are rapidly covered by luxuriantly growing mosses which are often accompanied by *Calluna* and *Vaccinium Myrtillus*; the moss-tussocks grow higher, and the intermediate hollows fill up with more mosses and sub-shrubs. As this luxurious vegetation gradually dies and is replaced by younger plants, the remains accumulate and form a peaty humus layer; in the course of time this layer becomes deeper and more peaty, and as a result mineral matter becomes less available for the plants growing on the surface. There is thus a gradual decline in the number of 'better' type plants, and an increase in the number indicating poor conditions; the peat accumulations block the natural drainage channels, making the ground sodden; *Sphagnum* species and such mosses as *Breutelia arcuata* and *Leucobryum album* replace the original mosses; *Erica tetralix* supplants the *Calluna* which has become poor in size and vigour, and the surface

peat becomes one of the worst types known. From the evidence presented in the Loch Tulla district there seems to be little doubt that the area now under plantation was natural forest not long before it was planted. The parts where planting was a failure—where there is now a *Scirpus/Calluna* vegetation on a considerable depth of fibrous peat overlying the original woodland humus—were undoubtedly the farthest advanced in the process of deterioration at the time of planting, and it seems certain that had the now wooded area not been planted they would by the present time have reached a moorland state on which it would be exceedingly difficult to establish trees.

TREE GROWTH.

The wood consists principally of spruce, and the survey was confined mainly to where this species was growing on peat. There are several large areas of pine, however, and both it and European larch are scattered singly among the spruce in most parts of the wood. A special study was made of the trees uprooted by the storm of January 1927; from these the age of the plantation appears to be about seventy years, and there is little evidence of any beating up having been carried out. No records were, however, available as to the actual date of planting, the method employed, or the percentages of species used. The growth on the six different types detailed on p. 86 and 87 is discussed below.

On Type 1 (trees forming a canopy on mineral soil), where well sheltered and on the rich soil of the deep ravine, some of the spruce were of quality Class I, being over 90 feet high; here one tree measured 93 feet and had a breast-height quarter-girth of 14¾ inches. Between 900 and 1,000 feet elevation, spruce on a knobbie where there was less than 3 inches of peaty humus was about 55 feet high with an average quarter-girth of 8½ inches; these trees are about quality Class V. In different parts of the wood, measurements of trees on this type lay between these just mentioned; there were, however, some with larger girths—up to 18½ inches quarter-girth being obtained.

The depth to which Norway spruce roots had descended into mineral soil was found by examination of several uprooted trees. It was over 2 feet in every instance and frequently over 4 feet; it was noted that the lateral spread of the uprooted portion of spruces on mineral soil was much less than was the case where this species had been uprooted on peat. Comparatively few spruces had, however, been blown over on the mineral soil sites.

Three of the largest Scots pine found on this type measured from 63 to 70 feet high, and had breast-height quarter-girths of from 11½ to 15¼ inches; possibly these trees were natural, however, and might be very much older than the planted Scots pine in the plantation. As a rule the pine on the drier knobbies were healthy in appearance though small—usually about 40 feet. Under similar site conditions the European larch were much taller than the pine; one measured 78 feet high, and at breast-height had a quarter-girth of 13¾ inches. With both the pine and the larch, roots descended over 3 feet into the soil, but the lateral extent of the uprooted part was much less than in spruce.

Perhaps the most interesting information was obtained from the study of growth on Type 2 (i.e. spruce in canopy on rich drained peat). Comparatively few trees on this type were blown down, and the data collected referred chiefly to standing trees. All along the strip by the roadside there are fine groups of spruce on this type; at 750 feet elevation the trees in one such group were from 75 to 87 feet in height, quarter-girthing from 14½ to 19 inches; this was on 6 to 18 inches of peat, the original drains in which were still clearly traceable. One of the largest trees in this group was blown down, and its roots were found to have descended 2 feet or more into the ground; the extent of the upturned root was 20 feet by 10 feet. These trees come into quality Classes II and III of the British Yield Tables; they all appeared vigorous, and had fine healthy brown stems. In other parts of the plantation the growth on this type was found to be similar to that of the group mentioned. At 650 feet one large tree growing on 10 inches of peat over gravel had a quarter-girth of 21½ inches; at a similar elevation in another part of the wood where the peat was 2 feet deep, the upturned roots of a large spruce were 15 to 24 inches thick; and alongside, another tree of large size had been broken off a few feet above the ground instead of uprooting; drains had been about 7 yards apart, and probably the efficiency of the drainage system in many of these sites was largely responsible for the strong rooting of the spruces. A tenth-of-an-acre plot measured on this type, where the peat was well drained and from 18 inches to over 3 feet deep, gave a volume of between 3,000 and 3,500 cubic feet per acre; this does not include a number of Scots pine which had grown to a fair size among the spruce. The spruce—excluding suppressed stems—ranged in height from 60 to 80 feet, and in quarter-girth from 6¾ to 17½ inches. To obtain an idea of the rate of height increment on this type an analysis was made of two trees which had been blown down. The first, at an elevation of 650 feet on 3 feet of peat, was 79 feet high, and its breast-height quarter-girth was 22½ inches; it had an upturned root system extending to 28 feet by 14 feet with roots descending 2½ feet into the peat. The second, at 900 feet elevation, measured only 56 feet high with a quarter-girth of 15¼ inches; it was on 3½ feet of peat and the root system extended laterally 15 feet and had descended about 18 inches into the peat. The first, plotted beside the standard 60-foot curve for spruce, follows the latter very closely, while the second falls 12 feet before the 40-foot curve at twenty years and, crossing at forty-five years, is 10 feet higher than this curve at sixty years.

On Type 3 (less dense woodland, deep peat, and wetter) there are many flush hollows both in the roadside strip and in other parts of the plantation, and one large area of this type lies towards the north of the shooting-lodge. Here many trees were blown down by the gale of January 1927, and there had evidently been much windfall in previous years also. Neglect of cleaning the drains was probably responsible for much of the uprooting, and may also have been the cause of the large number of undersized trees. On this type, at about 900 feet, the trees were uneven in size, ranging in height from 35 to 60 feet and in quarter-girth from 5¼ to 12 inches (i.e. quality Class V). The

peat was over 3 feet in depth, but in no case had the roots descended more than 12 inches, although the spread was often as wide as 28 feet, and the upturned part 10 or 11 feet high. One of these trees was analysed for height increment, and the curve was found to be very similar to the quality Class V curve. In this group, and in all trees on this type, roots were very superficial. Looking from the under side of an uprooted tree the five or six main roots were seen spreading out in a star shape. Rootlets did not descend as on mineral soil and drained peat, but were all confined to the surface layer. In many cases three or more trees had been torn up in one mass: one long bank of the roots of three trees measures 50 feet long, and was 12 feet high in places; as in other instances the roots had never entered farther than 12 inches into the peat, and large portions of them were only 6 inches below the surface. At an elevation of 650 feet four spruce trees ranging from 50 to 74 feet high, and from 6 to 12¾ inches quarter-girth, were analysed and their height-increment curves plotted; they fell into quality Classes III and IV. The ground was often very wet, and although in many cases drainage might have been inadequate from the time of planting, it appeared probable from one height curve that the drains had become blocked about twenty-five to thirty years after planting, as growth fell away rapidly from that time. Two of the other trees analysed on this type had curves which approximated closely to the standard 60-foot curve, while the fourth, which was on very wet ground, had started extremely slowly and was still below the quality Class V curve when blown down. Scots pine, where present, were usually small, and European larch were bent and cankered on this wet ground.

Unless in the drier places on Type 4 (alluvial peat areas; drainage usually poor) growth in height was usually shorter than on Types 1 and 2. Norway spruce averaged about 65 feet high and about 11 inches quarter-girth (quality Class IV). The peat was very irregular in depth, and near the bridge several trees were found to have grown on a layer of soil which had been deposited on the top of deep peat. One such spruce which had been blown down was 81 feet high and its quarter-girth at breast-height was 13¾ inches; another near by, and of about the same dimensions, had torn up with its roots a mass 25 feet long and up to 13 feet high; the top 9 or 10 inches was mineral soil—below was peat. On the east side of the road there are some very wet, badly drained areas of this alluvial type with small, undersized spruce which averaged about 25 feet high and 4 inches quarter-girth at breast-height.

The largest areas of Type V (thinly stocked, pure pine areas on *Molinia*) are found between the roadside strip and the deep ravine; they vary in quality and there is probably a definite connexion between the original intensity of the drainage, or the state of the drainage at present, and the quality of the ground for timber production. On one well-drained part, where the drains had been opened at regular intervals of 9 yards and where there was over 3 feet of peat, Scots pine averaged 65 feet high—equal to quality Class II, but the pine seldom were much over 50 feet on the pure areas, or quality Class III. Norway spruce growing beside the tall pines just referred to were

about 70 to 75 feet high. There are large areas where the peat is of a worse type and where drainage is inadequate, in which the Scots pine averaged not more than 25 feet; in these areas, which are small, it is doubtful whether or no spruces were planted among these pines, but occasional Norway spruce were found and are developing very slowly. Near the north-west edge of the plantation the pine averaged 25 to 35 feet, while two spruce trees found among them were 31 and 22 feet high respectively; this was on 2½ feet of peat covered by a *Molinia/Eriophorum* vegetation. In other areas there seems to have been a fair percentage of spruce planted with the pine; it would appear, however, that the ground was less suitable for spruce at that time than it is to-day—probably there was a dominant *Calluna* or *Scirpus* vegetation prior to draining and enclosure which would result in the spruce checking very severely, and ultimately dying off, before the full effect of the drainage and of the shelter from the Scots pine could be felt. Drainage must have brought in *Molinia* in much greater abundance, and if this ground was drained again and planted with Norway spruce the trees would probably do well. It is rather doubtful whether the pines have improved the ground to any great extent—they are never close enough to provide complete canopy—or whether the improvement may not be due to the gradual effect of the drainage. A plot of one-tenth acre, measured in a uniform area of pine growing on well-drained peat which was over 3½ feet deep, showed the yield to be about quality Class III. The height, even of the dominant trees, was very uneven, ranging from 30 to 60 feet. Two spruces outside the plot were about 70 feet high, and gave breast-height quarter-girth measurements of 12¼ and 16 inches respectively. The elevation of this plot was 680 feet, the ground was almost level; the top 6 inches of the peat was non-fibrous, underlying this there was 18 inches of tough, fibrous matter, below which it was sloppy and non-fibrous.

On this same type of ground there were occasional very fine larch trees; one standing on 3½ feet of peat was about 65 feet high and had a quarter-girth (at breast-height) of 11¼ inches; the elevation here was 700 feet, the vegetation *Molinia*/mosses, and the ground had been well drained by drains 8 yards apart.

Type 5 (practically treeless areas) occurs chiefly above the ravine and above the avenue leading to the Forest Lodge. In the latter area much of the ground is haggy; only an occasional Scots pine remains alive and these are seldom more than 15 feet high. Of the large, almost treeless areas north of the ravine, a considerable portion is of poor *Scirpus/Calluna* vegetation on thin, tough peat, but much more is on deep—over 3 feet—peat on an even slope where *Molinia* has come in on the drain sides. As these are 25 yards apart it is possible that the ground would have been under a fair crop of trees, growing on pure *Molinia*, had drains been opened at 7 to 9 yards apart as in other parts of the plantation. The large area between the Allt Bhreachnais and the loch-side appears much like some of the poor areas elsewhere, but it is almost certain that the fire is responsible to a great extent for the high percentage of ground in which *Scirpus* is dominant.

DISCUSSION.

The chief points of interest in the above investigation may be summarized as follows:

(1) The presence of woodland humus below the surface peat indicates that the area was formerly under natural forest. As this old forest gradually disappeared the land deteriorated, and it is probable that when the existing plantation was established some seventy years ago the process of retrogression to moorland conditions was already far advanced. Conditions would thus be unfavourable for the re-establishment of a tree crop except in the more favourably situated (flush and alluvial) areas. On the other hand, there can be no doubt that when the plantation has succeeded the result has been to maintain the fertility of the soil at a comparatively high level.

(2) The plantation bears an encouraging testimony to the potentialities of tree growth on relatively deep peat. Peat is sometimes spoken of as the least favourable type of soil for producing timber, but here we have trees from 80 to 90 feet in height with individual trees up to 19 inches quarter-girth (at breast height) and over. Admittedly, different types of peat vary in quality as widely as different types of mineral soil, but there is a better prospect, by means of proper drainage and under tree canopy, of improving the quality of a poor peat than there is, for example, of converting a poor sand into a productive medium for growing timber.

(3) The evidence as to the effect of intensive drainage upon the root development of spruce and upon the stability of the trees under wind pressure is perhaps the most significant result of the investigation. It has been shown that with efficient drainage spruce will develop a massive root system extending at least 2 feet downwards into the peat, and that this provides an effective anchorage against gales, even of the order of the great storm of January 1927 which wrought so much havoc in all parts of Scotland. On the other hand, when drainage was inadequate the spruce developed a very extensive but wholly superficial root system. Under strong wind pressure the shallow and often interlacing roots of the trees are torn bodily from the sodden peat below.

It would appear that in this area of high rainfall, main drains—i.e. drains cut down through the peat to the mineral soil—must be spaced at not more than 7 to 10 yards apart to be effective. The cost, at the present-day cost of wages, of such intensive drainage would be very heavy—say from £5 to £10 per acre, or even more—but this may not be too high a cost to pay for the reclamation of otherwise totally unproductive land.

In conclusion I wish to thank the Forestry Commissioners for permission to publish this article, which is based on an official report.

A GENERAL REVIEW OF POST-WAR FORESTRY IN CENTRAL EUROPE

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PART II[1]

THE PRESENT TENDENCIES IN SILVICULTURE AND MANAGEMENT IN GERMANY

THE unfavourable conditions after the war and the necessity of economizing in all raw materials have necessitated the search for methods of increasing forest production and the efficiency of forestry as a whole. The leading principles in silviculture and forest management were reconsidered, and an effort was made to find methods of treatment which follow natural laws.

In Germany after the war there was a burning desire to reform, and this started first in silviculture, proceeded to forest management and forest economics, and finally penetrated into the principles of forest administration and organization.

Many of these new ideas—some are only old ideas revived—will undoubtedly play an important part in the future development of forestry, but few of them can be applied in the extreme form in which they were first suggested. One can best understand them by looking back in the past history of German forestry. Since the year 1830 the yield from German State forests has doubled; this is the result of systematic management based on scientific knowledge. The unregulated single-tree method has been given up, and regular felling with careful regeneration introduced. Intensive thinnings not known before were started. Forest servitudes were brought out, stocks of game reduced, and the forest better protected. Forests in remote places were opened by improved means of transport, rendering more intensive management possible. Rotations were lowered from their previous high figure. The forest rent increased slowly but regularly, and Germany was well satisfied with the results of her forestry under the favourable economic conditions which marked the pre-war period. This well-ordered state of affairs was, however, artificial and based on a rigorous system of sustained yield or on Pressler's mathematical theories. The clear-felling system with artificial regeneration became the predominant method, and uniform even-aged coniferous woods, not unlike the ideal form of a mathematical normality, resulted. They were unable to resist all natural dangers from storm, fire, and insects, or to preserve the productive powers of the soil, or even to use them in a rational way. However, this management was regarded as the summit of forest art, whereas the natural form of uneven-aged mixed forests was looked upon as a thing of the past. But the consequences

[1] Part I in *Forestry*, i, pp. 55–61.

of this artificial order followed, and windfalls, insect calamities, deterioration of soil, and failures of artificial plantations destroyed the uniform woods, and stimulated a counter-movement which aimed at a return to nature. There was a return to natural regeneration, the creation and tending of mixed crops, and an avoidance of clear fellings, the father of this new movement being Karl Gayer, perhaps the greatest silviculturist who ever lived. Silviculture based on natural science began to develop, and a most important literature in silviculture was built up. Step by step these sound ideas penetrated into progressive practice.

The aim of this new silviculture is to increase the sustained forest-production to the highest possible point. The first requirement is a type of forest treatment which nowhere interferes with the natural laws of forest biology. Only a forest in perfect health, and subject to a treatment which follows natural laws, is able to produce permanently the highest possible yield. But wherein rests the health of the forest? In the harmonious co-operation of all its parts.

Based on the old but excellent views of Rossmässler, modern silviculture looks at the forest as an organism, made up of different parts: crop, soil, soil vegetation, soil fauna, and so forth. The health and even the existence of all these parts depends on an uninterrupted mutual co-operation. It is of small moment whether we agree with Möller, who looks at the forest as a true organism, or with Dengler, who thinks that the name 'Biocoenosis' expresses more clearly this co-operation of all the parts of a forest—a co-operation, however, which is not so close as in a true organism. If any part of this biological complex is destroyed or hindered in its work by an outside influence, the whole system may be disturbed. This disturbance or paralysis extends step by step along the other links of the chain and the whole forest may be affected. This state of affairs is not infrequent in Central Europe, e.g. in the State forests of Saxony. It is the result of past treatment with its unnatural principles and its abrupt modes of acting, e.g. clear felling, which disturbed the harmony within the forest organism.

This conception, which applies the principles of organic co-operation to the life of woods, has found its way into the whole of modern silvicultural literature. This idea undoubtedly explains many difficulties in a satisfactory manner, and when further developed may offer a new foundation to the technical side of forest production.

The chief consequence of this idea is the postulate of a general continuity in all silvicultural procedure. The idea of an organic whole excludes *a priori* all abrupt changes. Silvicultural treatment should be done in such a way that the forest 'would not be aware of it', as Möller says. One can easily see that only the selection forest corresponds fully to this requirement, hence the special liking in Germany to-day for the methods of treatment approaching to the selection forest. These methods are far from being abrupt. Fellings are carried out every year on the whole area. The productive power of the soil is best preserved, while sun energy and carbon dioxide is used more efficiently than in an even-aged crop where the crowns of the trees are all at

an equal distance from the soil, and there is a big gap between the leaves and the soil. The clear-felling system represents the opposite view, because it destroys the organic co-operation of all the parts of a forest. There is now general condemnation of this system in Germany. All the other silvicultural systems range themselves between these two antipodes, as was clearly demonstrated by Dengler at the meeting of the German Forest Society in Salzburg in 1925.

The postulate of continuity affects also the mode of thinning and the tending of woods in general. The interval between thinnings in common practice in Central Europe to-day, namely five to ten years, is regarded as too long. Thinning has to be too heavy if the interval is of that order, and there is thus a break in the continuity; the transition from one state of density of a crop to another is without a sufficient number of intermediate steps. In nature the spacing of trees changes continuously, and this requires a more continuous mode of thinnings: the ideal would be *annual* thinnings. There is no separation between intermediate and final fellings in this new theory; thinnings proceed slowly, without interruption to regeneration fellings.

The most notable practical example of this new silviculture is Herr von Kalitsch's forests at Bärenthoren. There a system since called *Dauerwald* [1] has been practised for several years. It corresponds exactly to the requirements of continuity demonstrated above.

The particular system of working there, and also at Höhenlübbichow and Eberswalde, is, however, based on particular local conditions, and should be viewed rather as an example of the general idea than as a concrete system for universal application.

THE AUSTRIAN MONARCHY.

In consequence of the break-up of the old Austrian Monarchy, and of the creation of several new countries, a new *status quo* in forestry has arisen in these parts of Central Europe. The subject will be developed historically, starting with the pre-war conditions.

The total forest area of the old Austrian Monarchy amounted to:

9,768,920 hectares,[2]	32·6	per cent.	of the total land area	in	Austria.
8,930,961 „	27·5	„	„	„	Hungary.
2,572,664 „	50·2	„	„	„	Bosnia-Herzegovina.

This was, per head of population: 0·3 hectare in Austria; 0·43 hectare in Hungary; 1·62 hectares in Bosnia-Herzegovina.

The total annual wood-harvest yielded about 57 million cubic metres,[3] out of which 27·5 millions were timber. The home timber consumption amounted to 19–20 million cubic metres, hence there were 7–8 million cubic metres free for export. The Monarchy exported most of its timber to Western Europe, namely to Germany 82 per cent., Italy 5·7 per cent., Rumania 4·6 per cent., Russia 3·6 per cent., and the remainder to France and Switzerland. Bohemia,

[1] *Forestry*, i, pp. 78–81.

[2] 1 hectare = 2·47 acres.

[3] 1 cubic metre = 35·32 cubic feet.

Moravia, Silesia exported chiefly to Saxony by rafting on the rivers Moldau and Elbe. Galicia exported to eastern Germany by rafting on the Vistula or by rail to western Germany. The northern parts of the Austrian Alps exported chiefly round timber to Germany, whereas from the southern parts sawn timber was sent to Italy. The eastern Carpathians and Transylvania used to sell round timber to Russia; it was rafted on the rivers Dniester and Pruth. Sawn materials went to the countries round the Mediterranean Sea, the Near East, and also to more remote places like Rotterdam in Holland via Galatz and Odessa. Bosnia and Herzegovina had no definite export markets, whereas southern and eastern Hungary, producing mostly oak and beech, exported via Trieste and Fiume.

In Austria the ownership of forests was as follows: 7·4 per cent. State forests; 8·0 per cent. funds and ecclesiastical forests; 14·2 per cent. forests of communities and co-operative societies, and 70·4 per cent. private forests, out of which 14·0 per cent. were entailed. The State forests were concentrated more or less in the high mountains, and the management therefore had to deal with all the unfavourable natural conditions of such localities, and in addition there were numerous forest rights and servitudes. The value of the State forests was estimated at nearly two million gold kronen, but the return was not high. They were managed on a basis of sustained yield, controlled by working plans, but transport difficulties often made intensive utilization impossible. Forests belonging to different funds, mostly ecclesiastical, were administrated by the Government forest officers, and the forestry, although not intensive, was still well developed—famous examples of timber transporting systems can be seen in the fund-forests in Bukowina. The communal forests were concentrated chiefly in Tyrolia, Dalmatia, Galicia, and Bohemia. The forestry was much poorer than in the State and great private forests. The same is the case with the forestry of *small* forest-owners. The *great* private forests were concentrated chiefly in Bohemia, Moravia, Silesia, Galicia, and Styria. The forest management in the great private forest estates in Bohemia, Moravia, and Silesia was very highly developed and a splendid example of forest work in all branches.

The forests of Hungary consisted of 16·4 per cent. State forests, 49·1 per cent. communal forests, and 34·5 per cent. private forests. The Carpathians and the mountainous parts of eastern Hungary were richest in forest. The great plain in the centre of the country, called 'Alföld', was poorest in woodland, although 700 years ago it also was covered with forest. The reafforestation of these plains was started several years ago, and extensive sandy areas were planted up with *Robina pseudacacia*. The principal species in the Carpathian mountains are Scots pine, silver fir, spruce, and beech. In the eastern regions, e.g. Siebenbürgen, beech, oak, and Scots pine are found. Hungarian forestry was progressive, although the management was not intensive. The State has done much to open up the forests by systems of transport, and thus makes more intensive management possible. It also helped afforestation by grants of money and by supplying cheap plants. The forest law in Hungary

was a most excellent one; all forests excepting the private ones were controlled by the State.

Bosnia and Herzegovina was a Turkish province until 1878. Out of the total forest area 76 per cent. were State forests. The forests were overburdened by servitudes and exploited by different commercial companies and timber merchants, the contracts being often unfavourable to the State. In addition the forests were devastated also by the local population.

THE NEW REPUBLICS.

The forests and the chief problems of forestry in the different new countries which were created after the division of the old Monarchy depend on the natural and economic conditions of the inherited forest area and its standard of development in forest management.

The new Republic of Austria inherited the alpine forests with all the unfavourable natural conditions in high mountains; forests with often primitive, and in many cases undeveloped, transport systems, and usually overburdened with forests rights and servitudes.

The Czecho-Slovakian Republic succeeded to the flourishing forestry of Bohemia, Moravia, and Silesia with their splendidly managed private forests, and favourable natural conditions in a relatively densely populated country. In Slovakia this republic inherited the vast resources in the Carpathian mountains.

Hungary is the poorest heir of the Monarchy; it delivered over 19 per cent. of its former forest area to Czecho-Slovakia, to Jugo-Slavia nearly 21 per cent., to Rumania more than 30 per cent., and a little also to Austria, so that little remains of all the great forests of the old country.

The new Republic of Austria, rich in forests but thinly populated, is a timber-exporting country. The forest area forming two-fifths of the total productive area extends to about 3 million hectares. The annual wood harvest yields about 8 million cubic metres or 3·08 per hectare.[1] The home consumption is about 6 millions, hence 2 millions are available for export, principally to Germany and Italy. Of the total forest area 13 per cent. is State forest, 10 per cent. belongs to the public funds, 10 per cent. communal forests, 7 per cent. is entailed, and 60 per cent. represents private forests. Naturally one would expect that the big forest-owners would be concentrated in the Alps where extensive forestry is more or less typical, and that the small forest-owners would be found in the flat woodlands with more intensive forestry; but just the contrary is the case. In the last century many servitudes in the Alps were bought up and paid for by woodland, hence many peasants became small forest-owners. In the Alps 70 per cent. of the forest area is in the hands of small forest-owners having less than 500 hectares, and only 30 per cent. is

[1] This figure does not correspond to the annual increment, because a very large volume of smaller wood, namely, branch wood, cannot be realized owing to the difficult conditions of transport. The annual increment was calculated at 10·5 million cubic metres or 4·00 per hectare.

in the ownership of large land-owners. In the flat country the respective figures are 60 per cent. and 40 per cent.

Out of the total forest area 73 per cent. are pure coniferous forests, 7 per cent. pure broad-leaved, and 20 per cent. mixed woods. The principal species are spruce, forming 55 per cent. of the forest area, silver fir 15 per cent., beech 15 per cent., larch 7 per cent., Scots pine 4 per cent., and Austrian pine, *Pinus cembra*, oak, maple, ash, elm, &c., the remainder.

Corresponding to the mountainous character of the forests 13 per cent. are protection forests, forming the highest crops below the alpine grazing areas. But if we take the total forest area in the high mountains only, and do not bring into account the flat country, the proportion of protection forests is considerably higher, forming about 25 per cent. The greatest part of forest area is managed as high forest, only 200,000 hectares are coppice or coppice-with-standards.

Over 80 per cent. of all Austrian forests are situated in the Alps, hence a feature of Austrian forestry is management in high mountains. One of its greatest problems is the establishment of proper systems of transport. The aim of most alpine forests was formerly the production of firewood and charcoal. The forests have had to supply the well-known iron- and salt-mines, and different local industries connected with these mines.[1] The firewood was transported chiefly by floating, and all the different systems of water transport were developed admirably in Austria, e.g. in the Salzkammergut. This necessity of supplying great centres of firewood consumption helped also, at a relatively early stage, in the development of a certain regulation of yield, namely methods based on volume (e.g. Pfannhauswald für Hall in the year 1555, Hallstadt 1561, Forests of Austrian and Styrian salt-mines 1561, &c.). The only silvicultural methods applied at that time were an unregulated single-tree system and the clear-felling system. In order to make the greatest possible profit from the transport systems, these clear cuttings were carried out on large areas, and the afforestation of these blanks presented great difficulties. A form of forest devastation followed this extensive forest utilization, and on unfavourable localities, for example on the southern slopes of the calcareous alps, the soil became exhausted and silver fir and beech, which once formed an important mixture, decreased in amount. Afterwards, this was carried further by the misguided application of Pressler's ideas favouring pure even-aged spruce crops. These became dominant over large areas, forming stands which were not sufficiently resistant to storms and to bark-beetle attacks.

The coming of railways changed the whole conditions. The demand for firewood decreased steadily, whereas the demand for timber began to increase. A new problem, the changing over from production of firewood to timber, had to be solved. This involved a change in the system of transport from water to land, the old system being unsuitable for timber transport.

The development of land transport is not yet complete, and forms one of the

[1] The beginnings of Austrian gold, iron, and salt mining can be traced back to Celtic settlements.

most pressing problems of Austrian forestry, because efficient transport is the basis of intensive silviculture and management. However, there are excellent examples of efficient extraction methods in high mountains to be seen in Austria.

The present position of silviculture in Austria and its tendencies will now be described briefly. Until now, the clear-cutting system is often the principal method in the large forests, but in many of them a promising start has been made with the introduction of more intensive systems. One of these is the strip system, carried out either as a narrow clear-cut strip, or as a shelterwood strip system.[1] The strips run more or less down the slopes. The ideal is to limit the breadth of the strips to the height of the trees, and not to proceed with fellings before the regeneration of the last strip is complete. The tendency is in the direction of creating, where possible, mixed crops and again to introduce silver fir and beech where these were eliminated by primitive forestry. Natural regeneration should be made use of wherever possible, and following the views of Cieslar and Engler local climatic races should be preserved. A highly developed and intensive shelterwood system is only possible under favourable conditions, particularly of transport.

Most of the larger forests are managed under working plans; the method usually applied is a combination of the age-class method and Judeich's management by compartments.[2] Rotations were high before the war, and these are now being reduced. Conditions in the high mountains require certain important modifications in forest management, but these cannot be described here.

The existing forest law issued in the year 1852 aims at the conservation of forests by prohibiting the clearance of forest except under special licence, by insistence on the afforestation of blanks within a certain time, and by prohibiting forest devastation. The size of a forest area which must be managed by a trained forester is fixed by different provincial laws.

Forestry education is very highly developed. The College of Forestry of Vienna and the Forestry Research Institute in Mariabrunn near Vienna are well known through the work done by Guttenberg, Cieslar, Micklitz, Schiffel, Breymann, and others. There is a forest school for the training of executive review forest officers in Styria, and there are also several lower forestry schools for the training of forest rangers.

The present tendencies in forestry in Czecho-Slovakia are interesting from several standpoints, but chiefly from that of forest policy. Among the different new countries which succeeded the old monarchy this young republic has inherited the most valuable forest resources. In the western region, Bohemia, Moravia, and Silesia, there is the highly developed forestry of the great private estates, and in the east, although management is not so intensive and in some

[1] Wagner's system is also applied. Its introduction is recommended on the sunny southern slopes.

[2] A description of this method as now applied in many of the great forests in Central Europe was published by the late Theodor Micklitz, Professor in the Vienna College of Forestry. See also Dr. Ing. Franz Heske, *Journal of the Cambr. Univ. For. Soc.*, 1926.

instances the forests are not yet opened by systems of transport, there is much forest wealth.

Unfortunately, forestry in Czecho-Slovakia is in the grip of politics, and political considerations rather than forest needs govern forest policy.

Political power and influence has been redistributed in Czecho-Slovakia, and naturally this is resulting in changes in social and economic conditions. Unfortunately, the changes are taking place so fast that adjustments are difficult. Amongst the classes which were brought by the revolution into the disagreeable situation of having the smallest political power, and thus able to give little resistance, are the great land-owners, who have in their possession a very great part of the total forest area. These families had an important influence in the old Austrian Monarchy, but they have lost almost all their power. It is not to be wondered at, therefore, that this class had to contribute a great deal to secure the economical basis for the new conditions. As the outcome of these political conditions, several laws have been passed providing for the expropriation of land beyond a certain area. Farm-land was divided and distributed after expropriation amongst different classes of small land-owners, and forest-land was and will be given up undivided to the State, the communities, the towns, the co-operative societies, &c. These laws have been in operation for several years.

The danger of this land reform from the standpoint of forestry comes chiefly from the method of application. According to the present laws 250 hectares is the maximum size of forest area which can remain finally in private hands. Compensation for the expropriated land is much less than its real value. The law provides compensation corresponding to the value during the period 1913–15, but this value is paid in the present depreciated currency, although the pre-war value represents a sum in the gold currency of the old monarchy. A board for land reform, founded in the year 1919, is in charge of carrying out these expropriations—it may be that the expropriations will not go so far as to impose a maximum of 250 hectares—but nobody knows how far they will go. This general uncertainty is a great menace to forestry. The owner previously regarded his forests as a sort of savings bank, as well as an object of affection and pride, but now he has no inducement to invest money in them. Again, what will be the future of these forests brought suddenly into the hands of owners who have not a tradition of good forestry? Industry and agriculture recover relatively quickly after adverse conditions, but shortcomings in silviculture, and insufficient care of the forest as the result of disturbances and uncertainty, have lasting effects.

The following is a brief outline of the conditions and problems of forestry in Czecho-Slovakia. The data given were published in 1924 by the board of statistics of the Republic. The total forest area of the Republic amounts to 4,529,433 hectares. This area is distributed amongst the principal provinces as follows:

Western provinces.		*Eastern provinces.*	
Bohemia . .	1,512,153 hectares	Slovakia . .	1,548,361 hectares
Moravia . .	642,842 ,,	Carpatho-Russia .	612,284 ,,
Silesia . .	154,324 ,,		

In the western provinces investigations have been made to determine the distribution of forests in relation to elevation.

At an elevation of	0–300 m.	15·3	per cent.	of total land area	forest.
,, ,,	300–400 m.	25·9	,,	,,	,,
,, ,,	400–500 m.	32·4	,,	,,	,,
,, ,,	500–600 m.	32·0	,,	,,	,,
,, ,,	600–700 m.	35·4	,,	,,	,,
,, ,,	700–800 m.	47·4	,,	,,	,,
,, ,,	800–900 m.	52·8	,,	,,	,,
,, ,,	900 m. and over	57·4	,,	,,	,,

The higher land is, therefore, richest in forests, and these are increasing in importance.

The distribution of species is given by the following figures:

Bohemia:	coniferous forests	85·9	per cent.;	broad-leaved	4·7	per cent.;	mixed	9·4	per cent.	
Moravia:	,, ,,	61·0	,,	,,	19·1	,,	,,	19·9	,,	
Silesia:	,, ,,	62·5	,,	,,	7·3	,,	,,	30·2	,,	
Slovakia:	,, ,,	30·8	,,	,,	48·3	,,	,,	20·9	,,	
Carpatho-Russia	,, ,,	22·3	,,	,,	67·7	,,	,,	10·0	,,	
Average	,, ,,	54·6	,,	,,	29·6	,,	,,	15·6	,,	

	Bohemia.	*Moravia.*	*Silesia.*	*Slovakia.*	*Carpatho-Russia.*	*Total.*
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Spruce	57·2	41·5	59·6	22·3	25·4	39·2
Scots pine	27·9	15·1	4·9	—	—	14·2
Silver fir	4·0	12·2	17·7	11·0	3·7	8·0
Larch	1·2	1·7	—	—	—	1·0
Oak	2·5	7·1	—	15·4	7·9	8·2
Beech	2·0	8·5	9·8	31·8	58·8	20·7

Both tables show that the area of broad-leaved forests is greatest in the eastern provinces. This is largely the result of management; in the western provinces the area occupied by broad-leaved and mixed woods was formerly greater than now, particularly at the lower and middle elevations, but clear felling and afforestation with conifers have changed the composition of the forests. This change, which was typical of other parts of Central Europe, has serious disadvantages, and there has been a tendency in the other direction during the last thirty years. The management in many of the large forests in Bohemia, Moravia, and Silesia is excellent, and there are good examples of natural regeneration by different systems and of tending crops and soil according to modern principles. The total forest area is made up as follows:

	High forest.	*Coppice-with-standards.*	*Coppice.*
	Per cent.	*Per cent.*	*Per cent.*
Bohemia	97·2	0·6	2·2
Moravia	86·8	3·1	10·1
Silesia	98·4	0·1	1·5
Slovakia	84·6	0·9	14·5
Carpatho-Russia	99·0	0·1	0·9

The area of coppice, and coppice-with-standards, was greater formerly. The development of the forests for the production of timber rather than firewood is the principal cause of the decrease in the coppice area; this is restricted to river valleys and under 700 metres elevation.

It is very difficult to give figures showing present distribution of forest area amongst the different classes of owners, because the figures are changing from day to day as the result of expropriations of forest land. Immediately after the war the following figures indicated the distribution:

State forests	15·8 per cent.	31·4 per cent.
Communal forests	9·6 „	
Ecclesiastical and corporation forests	6·0 „	
Forests belonging to co-operative societies	9·5 „	9·5 „
Entailed forests	18·8 „	59·1 „
Private forests	40·3 „	

At present the area of State forests is undoubtedly much greater and that of private forests less.

The following are data regarding the area under working plans:

Working plans.	*Bohemia.*	*Moravia.*	*Silesia.*	*Slovakia.*	*Carpatho-Russia.*
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Managed under working plans	73·1	76·5	80·9	73·1	77·4
Managed without working plans	26·9	23·5	19·1	26·9	22·6

The larger forests are more systematically managed than the smaller.

Of the forests between 0 and 250 hectares, 12·9 per cent. of the area was under working plans.
„ „ 250 and 500 „ 63·9 „ „ „ „
„ of more than 500 „ 85·3 „ „ „ „

The rotations are longer in the State forests and in the large private forests than in the small forests.

Forest area.	*Rotations.*		
	60–80 years.	*81–100 years.*	*More than 100 years.*
	Per cent.	*Per cent.*	*Per cent.*
0–250 hectares	73·8	25·8	0·4
250–500 hectares	66·6	30·7	2·7
500–1,000 hectares	62·3	32·5	5·2
More than 1,000 hectares	26·6	54·2	19·2

The age classes are better distributed in the larger forests.

Forest size	*Area as a percentage.*					
	1–20 years.	*21–40 years.*	*41–60 years.*	*61–80 years.*	*81–100 years.*	*Over 100 years.*
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
0–250 hectares	28·7	26·7	22·3	16·9	5·0	0·4
250–500 „	25·8	23·3	21·3	20·0	7·4	2·2
500–1,000 „	23·8	24·6	22·2	19·9	7·2	2·3
over 1,000 „	20·7	21·1	17·6	16·7	14·4	9·5

The increment in cubic metres per hectare is higher in large forests than in smaller.

Area of forest.	*Bohemia.*	*Moravia, Silesia.*	*Slovakia.*	*Carpatho-Russia.*	*Average.*
0–250 hectares	2·4	2·5	3·0	2·5	2·6
250–500 „	3·2	3·4	3·4	2·1	3·2
500–1,000 „	3·2	3·8	3·4	2·7	3·3
over 1,000 „	3·7	4·4	3·7	3·4	3·7

Collecting of litter is practised to a much greater extent in the small forests and reaches 64 kilogrammes per hectare in small private woods.

All these figures show clearly that the management of small forests is much less efficient than that of large forests. Most of these small forests are not managed under working plans, they have short rotations, badly distributed age classes, poor increment, and there is excessive collecting of forest litter. The better management of these small areas is an urgent problem. In Bohemia 16·2 per cent. of the total forest area is distributed amongst small forest owners having less than 10 hectares. The total forest area of this kind is 250,000 hectares, and belongs to 100,000–150,000 different owners. The distribution of forest area according to the size of unit owned is as follows:

Size of forest.	*Percentage of the total forest area.*
0–250 hectares	23·8
250–500 „	3·8
500–1,000 „	4·5
over 1,000 „	67·9

On the other hand the management in the large private forests was generally good. Many of them had been in the hands of old aristocratic families for centuries, and many were entailed also. The head officers of these forests were often known as excellent foresters all over Central Europe. Foresters from abroad visited them and studied their methods of management. There is no reason from a forestry point of view why these great private forests should be expropriated and given to owners whose forestry up till now in many cases has not been good, in some cases has been very bad.

The following figures give the annual production of timber for the different provinces.

Bohemia	5·11	million	cubic metres.
Moravia	2·43	„	„
Silesia	0·76	„	„
Slovakia	5·10	„	„
Carpatho-Russia	1·87	„	„
Total	15·27		

This corresponds to 3 cubic metres per hectare; out of this 60 per cent. is timber, and 40 per cent. firewood.

The timber industry is well developed in Czecho-Slovakia and there are

numerous sawmills. The following two tables show the increase during recent years.

Province.	*Steam.*		*Water.*		*Electricity.*	
	1914.	1925.	1914.	1925.	1914.	1925.
Bohemia . . .	320	435	1,235	1,261	—	80
Moravia . . .	170	210	616	480	—	15
Silesia . . .	50	80	195	120	—	8
Slovakia . . .	26	170	57	287	—	6
Carpatho-Russia . .	2	18	11	20	—	8

The annual timber requirements of sawmills is 6 million cubic metres, of which 3·3 millions of sawn timber is produced. Of this production the following amounts were exported:

1920	602,559	cubic metres.
1921	721,118	„ „
1922	1,207,126	„ „
1923	1,160,964	„ „
1924	1,210,044	„ „
1925	965,049	„ „

The export trade is principally to Germany and Hungary, but also to the western countries, France, Holland, and England. The more important branches of the timber industry are paper-making, manufacturing of furniture, match factories, and impregnation works.

The progress in forestry in Bohemia is illustrated by the following figures:

1875 41 per cent. timber, 59·0 per cent. firewood.
1920 60 „ „ 39·6 „ „

1875 annual production, 2·9 cubic metres per hectare.
1920 „ „ 3·2 „ „ „

1875 67·6 per cent. of forest area were under working plans.
1920 73·1 „ „ „ „

At the beginning of the nineteenth century a great part of the forest area was managed on a primitive shelterwood selection system. By 1875 this method was practised on 246,000 hectares only, and by 1920 the corresponding area was only 93,000 hectares.

In the year 1920 the following numbers were employed in forestry in Bohemia, Moravia, and Silesia:

4,103 forest officers.
10,305 lower forest officers and forest guards.
16,230 permanent.
83,217 not permanent workers.

At present there are two colleges of forestry in Czecho-Slovakia: Prague and Brünn. The lectures are in Czech language. The German population of the Republic has had no opportunity as yet of being trained in forestry in a university in its mother-language. Besides these two Czech colleges there are several forestry schools training executive forest officers and lower forest officers.

SOME RECENT FOREST PROBLEMS IN SWITZERLAND

BY K. A. MEYER

The Swiss Station for Forest Research

EVERY five to ten years the Swiss Department of the Interior organizes a series of forestry conferences in order to give our foresters a general view of all the real forestry problems of theoretical or practical importance. The State gives facilities for the meeting of these conferences and nearly all the staff can take part in them; they are proving more and more fruitful. Such a conference has just been held at Zurich in March 1928. About 90 per cent. of all the forest officers in Switzerland were present, and it may be said that nearly all the important questions on forestry were discussed and some were solved. To read these reports, then, is to discover the problems standing in the foreground of Swiss forestry.

The discussions are conducted in one of the national languages of Switzerland, for the most part in German and in French. It must give an agreeable and unexpected impression to the foreigners who are present to hear these two languages together. Let me now say a few words about these conferences.

M. Pettimermet, Inspector-General of Forests in Switzerland, gave a *résumé* of the production in volume and value from the Swiss forests. He then gave a brief survey of the exports and imports of timber, forest management and the means of intensifying it. Note some results for Switzerland, 1st January 1927:

Forest area of all public woodland (confederation, cantons, municipalities)= 699,750 hectares (1 hectare = 2·47 acres).

The total forest area is made up as follows:

High forest	573,038 hectares.
Coppice and coppice-with-standards	50,943 ,,
Unproductive forest soil	75,769 ,,
Protection-forest	562,260 ,,

This last is very important in Switzerland.

Annual felling per hectare (1926):

In the State forests (confederation and cantons)	4·6 cubic metres. (1 cubic metre= 35·32 cubic feet.)
In the municipal forests directly managed	4·6 cubic metres.
In the other municipal forests	3·2 ,, ,,

Annual gross revenue 1926:

In the State forests	per cubic metre	35·1	Swiss fr.;	per hectare	159·8	fr.
In municipalities directly managed	,, ,,	33·8	,,	,,	157·7	,,
In other municipal forests	,, ,,	28·1	,,	,,	90·2	,,
The mean of all public forests	,, ,,	29·6	,,	,,	102·0	,,

Expenditure 1926:

In the State forests	,, ,,	19·8	,,	,,	90·2	,,
In municipalities directly managed	,, ,,	16·9	,,	,,	79·0	,,
In other municipal forests	,, ,,	13·1	,,	,,	42·0	,,
Mean of all public forests	,, ,,	14·3	,,	,,	49·1	,,

The annual net revenue 1926:

In the State forests . . .	per 1 cubic metre	15·3	Swiss fr.;	per hectare	69·6 fr.
In municipalities directly managed	„ „	16·9	„	„	78·7 „
In other municipal forests .	„ „	15·0	„	„	48·2 „
Mean of all public forests . .	„ „	15·3	„	„	52·9 „
In 1926 Switzerland imported . . .	693,000 tons of wood.				
„ „ exported . . .	55,000	„	„		
Consequently an excess of imports of . .	638,000	„	„		

Our forest authorities certainly hope that the deficit—as a result of the over-exploitation during the war, when Switzerland had to export wood in return for grain—will disappear, provided that the management and administration of the forests become still more intensive. Working plans have to be completed and renewed, and revisions ought to be made and repeated at short intervals. Great attention will be paid to the famous 'method of control', by the aid of which M. Biolley has obtained such brilliant results, which are known all over the forestry world.

Professor Knuchel spoke on the technical qualities of the timbers in current demand for industry and world commerce. In Switzerland the forester concentrates on the production of a good working timber. He gives preference therefore to well-grown broad-leaved trees, and also to close-grained alpine spruce, larch, and *Pinus cembra*. By special thinnings and other silvicultural operations it is possible to eradicate tree defects.

Professor H. Badoux, Director of the Swiss Forest Research Institute, an authority on all exotic tree problems, dealt with the Weymouth pine in Switzerland. This species is of the greatest interest throughout Central Europe. It was tried during several decades with satisfactory results; unfortunately, in recent years attacks by blister rust have made its cultivation of doubtful advantage. This disease had devastated a number of plantations. The careful researches of Professor Badoux have shown clearly, however, that, at least in Switzerland, the virulence of the fungus is diminishing, and that the Weymouth pine, treated according to his directions, can remain for the future one of the most valuable species introduced into Switzerland. Professor Badoux has also published his researches on *Pseudotsuga douglasii*.

Forstinspektor Dr. Fankhauser dealt with a subject peculiarly Swiss. For our alpine regions the knowledge of avalanches and defensive works against them is of the first importance. Protective works should not, according to the many new and fruitful experiments of this delegate, go beyond the upper limit of the trees. The greatest effect is obtained by horizontal walls which break the masses of snow. Reafforestation must always be carried out as an aid to special protective works. The forest in the regions where avalanches are frequent must be managed in the best possible manner and treated carefully. Some trees of otherwise little value are useful for protection against snow: such are *Alnus viridis* and *Sorbus aucuparia*; they should be favoured as much as possible. For the rest, the danger brought about by avalanches varies according to the conditions of mountains, snow, &c. When Dr. Fankhauser's report appears many beautiful photographs will show typical examples. The

observations of Dr. Fankhauser will be useful in Scotland, in India, in the Pyrenees, and in Canada.

The last subject is of interest only in alpine regions, but the next is of much wider interest. M. Aubert, forest inspector, spoke on motor traction by means of wood derivatives, the modern preparation of motor wood-fuels and its prospects of utilization. The question of these fuels is doubtless not unknown to readers of *Forestry*, seeing that it is discussed frequently in periodicals, particularly French, Belgian, and Italian. M. Aubert wishes to replace benzine by another means of propulsion obtained from charcoal. The idea did not originate in Switzerland, but it found an especially clear response there, because few countries are so poor in primary indispensable products. In our country we remember too well the world war, which caused scarcity not only to the belligerents but also to the neutral countries of Europe. Means of living, provisions, and raw materials were all at a premium. If one were to believe General Ludendorff, the failure of petrol and its most important product, benzine, would have decided the war. It is now proposed to utilize wood and waste timber in order to get a charcoal capable of producing a gas to replace benzine. Already some thousands of automobiles are fitted with new gas generators. Heavy artillery in France, and little by little in Switzerland, are already using this fuel for propulsion. In France, Belgium, and Italy competitions have taken place and they have resulted in solving the problem. When we think of former tendencies to employ alcohol along with benzine, it is seen that charcoals give a much more complete solution. The use of alcohol can decrease the consumption of benzine, the charcoal replaces it. It is true that we are uncertain as to the yield, the economy of charcoal-wood, and also the outcome for the sustained management of our forests. But Forest-Inspector Aubert, the chiefs of forestry administration, and the professors of our college are all convinced that the solution of the problem of gas charcoal will give rise to a new era in Swiss forestry.

All foresters know the classic researches of Dr. H. Burger, at the Swiss Forest Research Institute, concerning the physical qualities of forest and agricultural soils. Many of his numerous publications treat of this important matter of pedology. The editor of *Forestry* has said, with perfect reason, how 'much more complete knowledge of the soil in all its complexity' is necessary. The researches of Dr. Burger, which appeared in the *Mitteilungen* of the Swiss Forest Research Institute, are worth reading by every forester. In his last lecture Dr. Burger considered the physical properties of the soil and their influence on afforestation. In a convincing manner he showed that the forest has a much more favourable and continuous influence on the regulation of water than pasture and meadow land. But the optimum effect is attained only by a forest based and managed in such a way as to be able to produce quickly and permanently a favourable soil condition, loose and permeable. It is most fortunate that the ideal forest managed on our Swiss forestry principles gives at the same time the greatest and most sustained production of timber, the most favourable effect on the soil, and the regulation of water. Dr. Burger

drew a number of practical conclusions from his well-founded theories. Among others he showed how afforestation must follow along lines of botanical succession. At the time of floods the forest may not always sufficiently decrease the quantity of river water, but it will always diminish the masses of boulders carried down. Dams and other engineering constructions are only permanently effective when they are combined with afforestation. Foresters, agriculturalists, and engineers ought therefore always to work together. Dr. Burger affirms that the forest always plays its part in the regulation of water, and does it the better when we fulfil our duties to it. The interests involved are large.

Theory and practice blended ideally in the lecture by Professor Schädelin. He showed the actual state of Swiss silviculture and its aims. One knows that in Switzerland the selection system is of the greatest importance and gives the greatest success. But he made the observation that it is also necessary to give in our country the greatest attention to the irregular shelterwood system (Swiss *Femelschlag*).

From the management point of view the selection system was dealt with by Dr. Flury. He attempted to give the theoretical basis for a new method of management, combined with silvicultural requirements. He is endeavouring to find a means of site classification in the selection forest. The points of attack are furnished by the obtaining of the range of diameter classes in the different localities, together with the length of time taken for trees to pass from one class to the next.

Eminently practical problems have been treated by Kantonsoberforstmeister Weber and Oberförster Bavier. M. Weber proposed to find a uniform means of soil assessment—so long desired—at the time of forest expropriations, while M. Bavier is looking for a fixed basis for the classification of the different assortments of wood.

Staatsrat von der Wied and Oberförster Graf treated the subject: 'Fresh Aims of Silviculture and State action in order to attain them'. In Switzerland the forest area can hardly be added to. It is only by the most intensive management that production can be so increased that the deficit of a million cubic metres of wood can slowly disappear. Clear-cutting must disappear entirely and for always; the Swiss forests are to be treated by the selection system or by the irregular shelterwood system, with natural regeneration. The forest of the future will be cared for, like a beautiful house, in all its stories; all will be productive, while the soil and crowns will not be forgotten. Valuable species of trees will be favoured and introduced into forests of mixed coniferous and broad-leaved trees. The forests will be by preference uneven-aged and mixed. The lines of extraction and network of roads will be increased. The producers of wood will unite into commercial associations. Fresh working plans will be prepared for all forests, and these plans will be revised frequently with the help of subsidies given by the State. The reserve funds, which have already rendered such good service, are still in existence. The forestry districts must be small. The forest property of the State will be augmented as much as possible; it forms a safe investment for capital, the interest on which increases

slowly. The State forests can serve as a model for private forests, which, however, are not very numerous in Switzerland. Attention will be paid to the origin of seed. The State will subsidize forest societies, literature, forestry periodicals, and forestry tours. The School of Forestry has recently been presented with a fine forest, for the practical training of students. Forestry is very popular in Switzerland; it will be more and more esteemed and appreciated by all the population.

These are only a few observations on the most important problems of Swiss forestry. The proceedings of the conference of 1928 will be published in the course of the year, and they will give an adequate picture of our silviculture and many important results, which, without doubt, will be welcomed by those abroad. At the same time we must not forget our three monthly periodicals, the statistical volumes of the federal Department of Forests, Hunting, and Fishing, and—last but not least—the *Mitteilungen* of the Swiss Forest Research Institute.

A BIBLIOGRAPHY OF RECENT FOREST LITERATURE IN SWEDEN

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THE Swedish literature on the subject of forestry has only to a minor extent been published in book form, and most of it is to be found in periodical journals. Foremost among these publications may be mentioned *Meddelanden från Statens Skogsförsöksanstalt* (Reports of the Swedish Institute of Experimental Forestry), in this article abbreviated to *M.* The 'Svenska Skogsvårdsföreningen' (Swedish Forestry Society) publishes two journals, namely *Svenska Skogsvårdsföreningens Tidskrift* (Journal of the Swedish Forestry Society), abbreviated to *Skf.*, and *Skogen* (The Forest), designated *S.* Besides the above, there is the *Norrlands Skogsvårdsförbunds Tidskrift* (Journal of the Forestry League of Norrland), herein called *N.* Articles on forestry problems are also printed in other technical journals, as for instance in *Ekonomisk Tidskrift* (Economic Journal). For the sake of continuity it has been necessary in some instances to go back as far as the period before 1900.

The literature to be dealt with has been grouped as follows:

I. The production and consumption of timber in Sweden.
II. Forest economics.
III. Forest mensuration.
IV. Silviculture.
V. Forest technology.
VI. Soil science.
VII. Forest trees; the natural history and biology of forests.
VIII. Protection.

I. THE PRODUCTION AND CONSUMPTION OF TIMBER IN SWEDEN.

The question of how the country is using its timber supplies has been the subject of much discussion, and fears have even been expressed that the forests may gradually disappear because of excessive cutting. The papers by Kinnman (4), Jonson (5), and Petrini (7) are the result of inquiries made to throw light on this subject. The State, however, has begun to make a general national assessment of all forests, and the result will probably be ready, at the latest, about the year 1930. A beginning was made with one province, namely Värmland (1, 2, 6, 8). The Committee appointed to conduct the assessment has performed its duties well. A number of the methods which were worked out in the course of the Committee's labours have since been employed for purposes of national forest assessment both in Sweden and in the neighbouring countries, Norway and Finland. In addition to the assessments so far carried out (11) the members of the Committee have investigated the consumption of

timber and fuel for household requirements (10), and have calculated certain comparative figures (9) required for measuring timber.

II. FOREST ECONOMICS.

The building up of a tenable theory of forest economics has been a subject upon which many investigators in different countries have expended a great deal of effort. In Sweden, too, the interest in this difficult task has been very keen, and the different points of view have occasioned much controversy. Most of those who have written on the subject are to be found in the ranks of the foresters, but professional economists, e.g. Professor Heckscher (15) and Professor Ohlin (22) have also contributed to the literature. The question of the extent to which the principle of profitableness is applicable in silviculture has given rise to most discussion. The above-mentioned economists and also Ernst Anderson (13), chief forester, are among those who wish a strictly carried out assessment of the return from forests. The opposition is represented by P. O. Welander (26) and others. On the other hand, Tor Jonson (16–19) has taken up an attitude intermediate between these two extreme points of view. Recently these problems have been discussed on definite scientific lines by Mårn (21), who after several years of practical work in the sphere of silviculture has devoted a number of years to the study of political economy, specializing in the theory of forest economics, and he has now begun to publish the results of his investigations.

III. FOREST MENSURATION.

The problem of forest mensuration which has played the most important part in Sweden is undoubtedly the question of the form of the tree stem. Although other systems of classification have been tried, notably that of Sivén (60), it is almost exclusively the logarithmic equation for the curve of the stem published by Höjer (29) in 1903 which has come into practical use. The constants in this equation were first determined by Jonson (31), then by Söderlund (61), and finally by Petterson (56). An expression of form to characterize the relative tapering of the tree stem has been sought for by various authors. Maass (40) uses the fictitious form-quotient produced by the ratio between the diameter at the middle of the stem and the diameter at breast-height; Jonson (31 and 35) defines his absolute form-quotient as the ratio between the diameter at the mid-point between breast-height and the top of the tree and the diameter at breast-height; Heijbel (28) has tried to free his expression of form from the influence of root-swelling, and he therefore employs the so-called 'true' form-quotient, the ratio between the diameters at 50 per cent. and at 10 per cent. of the total height of the stem. Finally, Petterson (56 and 57) has introduced a quite general expression of form, namely the basic abscissa, xb, in that system of co-ordinates in which x represents the length of the stem, measured in certain units, when the diameter is the ordinate represented by the function $y = \log x$.

Tor Jonson (30–6), Professor at the Skogshögskolan (Academy of Forestry),

Stockholm, by the practical application of his mechanical theory that the structure of the tree stem is adapted to resistance of wind-pressure, has developed methods of forest mensuration, and his tables (35) are now in general use. Mattson Mårn (45 and 46), Petrini (49–52), Tirén (62–4) have continued the work, taking the mechanical theory as a basis, and devoting themselves largely to investigations carried out for the purposes of its application. Petterson (56 and 57), since 1926 head of the forest department of the Institute of Experimental Forestry, has defined the problem with precision and set it out anew in its various aspects. He has produced a new set of mathematical formulae which is proving of great value in the scientific investigations which are being carried out in that field. Amongst other interesting investigations the following may be mentioned: Hagelberg's (27) studies of the distribution around the average stem carried out in conjunction with Fekete's and Schiffel's works on the subject; Nordquist's (48) inquiries into the stem factors; Kolmodin's (37) analyses of the significance of the climatic periods for the growth of trees; Ronge's (58 and 59) graphic presentation of volume tables; and Petrini's (54 and 55) studies on the subject of methods for calculating the percentage of growth and formulae for the cubing of stems.

IV. SILVICULTURE.

In that section of forest literature which comes under the heading of Silviculture the problem of provenience plays a leading part. The most weighty contributions in Sweden towards the solving of problems in this subject have been made by the late Professor Gunnar Schotte (88, 92, and 95), while Wibeck (101), Eneroth (72), and Romell (86) have treated these subjects in an illuminating way. Allied problems are those dealing with the germinative power of seed, and the results achieved in forest cultivation and natural regeneration respectively. In this connexion should be named, besides the works of Schotte (87 and 89), those of Wibeck, (99, 100, 102, 103, 104, and 105); moreover, from the ranks of practical foresters should be recorded a number of important articles on this subject (73, 76–9, 81, 85, and 106). Professor Hesselman's work is in a class by itself, being based on a fundamental investigation into the condition and nature of forest soil. To the question of forest-production on drained ground much attention has been devoted in recent years (71 and 83), while in the sphere of tending woods one or two papers are worth noting on thinning, its practice and results (84, 90, 91, 94, and 98), besides which special mention should be made of Schotte's great monograph on the importance of the larch in the forestry of Sweden (93).

V. FOREST TECHNOLOGY.

A bibliography of the principal Swedish books and articles on this subject is given.

VI. SOIL SCIENCE.

The founder of modern forest-soil science in Sweden is Professor Henrik Hesselman, the present head of the State Institute of Experimental Forestry,

Stockholm. Having spent some time in the Island of Gotland studying the conditions affecting soil science (166), and afterwards carrying out certain investigations in Norrland in regard to ground-water and peat-bogs (see below), Hesselman concentrated his investigations on the humus layers of the Swedish forests and their biological-chemical properties, specially in regard to the conversion of nitrogen (134–6, 74, and 75). The object of all these investigations into humus is to discover the changes that the humus layer undergoes as a result of the various forms of treatment in the forest. This extension of our knowledge on the subject makes it possible to tend the soil along rational lines.

O. Tamm (144–9) has, with the aid of chemical analyses, thrown light on the question of the importance of the geological substratum for the growth of trees, and has also carried out useful work investigating the movements of ground-water, and the important part they play in the formation of swamps on forest soil—a subject on which Hesselman (133) has initiated valuable investigations, which have in part been carried on recently along fresh lines, above all through the contributions made by Carl Malmström (138). The latter is at present engaged upon an extensive investigation into the problem of bog-formation, which is due to be published in 1928. B. Halden (128–32) has devoted much attention to the study of the sequence of geological strata and its importance for the humidity of the soil, and von Post (140) has made an inventory of all the peat-bogs in southern Sweden. A large work, based on his own investigations, has been published by Romell (141 and 142) on the subject of aeration in the soil and its significance. This author has also written an illuminating article (143) giving a new and more precise interpretation to the law of productivity formulated by Mitscherlich.

VII. FOREST TREES; THE NATURAL HISTORY AND BIOLOGY OF FORESTS.

The immigration of forest trees into the country and the biological evolution of the forests have been the subject of close inquiry on the part of Swedish scientists, and at quite an early period there existed abundant literature on the subject. Among these earlier works should be mentioned those of Alb. Nilson (178–81), Rutger Sernander (193–6), and Gunnar Andersson (150–4). In the sphere of the evolution of forest trees and forest communities there are also the works of H. Hesselman (159–66), Holmgren (167–9), E. Wibeck (207), Nils Sylvén (200–6), and E. Hemberg (157 and 158). More recent investigations into the history of forests have been recorded, for instance, by von Post (188). Studies of vegetation have been carried out on bog-land by E. Melin (174), who has since devoted special attention to researches into the mycorrhiza fungi (175–7); investigations have been made in the rocky and mountainous regions by Th. Fries (156) and by G. Samuelsson (192), and in the forest areas by Carl Malmström (173) and others. T. Lagerberg (171) has published a paper on the methods of analysing soil flora. G. Nordfors (182–6) has studied from the point of view of forest biology certain conditions prevailing in the mountain forests of the county of Jämtland. Of peculiar interest is the work of L.-G.

Romell (191) in which he gives an account of the results of his investigations into the times of year when the growth of forest trees begins, culminates, and ends. Henrik Petterson (187) has published an explanatory brochure on experimental forestry activities with special reference to the physiological factors, and M. G. Stålfelt (197–9) has carried out a series of experiments with a view to explaining the assimilation of carbon dioxide in trees under certain conditions, in which he has obtained interesting results.

VIII. PROTECTION.

Much study has also been devoted in Sweden to the influences of fungi, animals, &c., injurious to the forest, particularly with a view to preventing damage. In this category come G. Lundberg's article (223) on forest fires and how to fight them. Mårn's account of the devastation caused by a storm in Dalarne (224) and of damage to young pine due to snow pressure (226) may also be mentioned in this connexion. The danger of breakage by snow has also been studied by Hesselman (229), Lagerberg (219 and 220), and Schotte (227 and 228). The fungous diseases have been investigated by Nils Sylvén (22) and above all by Professor T. Lagerberg (212–22), who has devoted much time to the discovering of their origin and biology.

Insects and the damage to forest trees caused thereby have been studied by foresters such as Kolmodin (37) and Hjalmar Sylvén (230–4), who have carried out valuable scientific investigations along with their practical work.

A great change took place in the entomological sphere in 1915, when a special Entomological Section was established at the State Institute of Experimental Forestry, at the head of which is Professor Ivar Trägårdh. The first function given to this section was that of working out a line of study and drawing up a system of classification with a view to ascertaining what insects have to be contended with, and what is their status as pests. In this respect great attention has been paid especially to the bark-beetles; see Trägårdh (237 and 240) and Spessivtseff (233 and 236). The connexion between thinning methods and the treatment of the timber on the one hand, and the appearance of pine-beetles and other bark-beetles on the other, has likewise been investigated (245), as also the part played by the climate in this respect. Other works deal with the insect fauna of spruce-cones (235 and 239), the general methods (249), analyses of dying trees (252), &c. Quite recently, too, the study of soil fauna has been made a part of the programme.

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REVIEWS

Silvicultural Systems. R. S. Troup, C.I.E., D.Sc. (Oxon), F.R.S. Clarendon Press, Oxford. Price 21*s*.

A review by A. K. Glasson

IN this book of just under 200 pages Professor Troup has given an account of the silvicultural systems at present practised in Europe and elsewhere, which fills a gap in the literature of forestry in the English language, and is the most important British publication in Forestry since Schlich's *Manual*. In Europe, where forestry has been practised for centuries, the procedures at the time of removing an existing crop and starting a new one have been continuously adapted in the light of experience to suit differing conditions and to meet to the fullest possible degree the silvicultural requirements of the trees, and a number of more or less clearly defined methods of treatment or 'silvicultural systems' have resulted. Each system is described generally, the practice and the principles underlying the practice being given in full detail. This description is followed by an account of the application of the system in certain selected forests and by a summary of the inherent advantages and disadvantages of the system. Preceding the general descriptions is an account of the terminology used in French, German, and English which will be found very useful. The book is illustrated by eighty-six excellent photographs and diagrams.

The book is well arranged and easy to read and will be valuable to every one connected with forestry. Although the author states in the preface that it is to be regarded rather as a guide to the practical study of the systems in the forest than as a means of acquiring a complete knowledge of silvicultural systems, those who have not the opportunity for such practical study will find the book an excellent substitute. For teaching purposes it will be invaluable, and forest officers in India and the Colonies have now available a work to which they can refer for help in the solution of their problems.

In two respects only is there scope for criticism. In the accounts of the origin and development of the different systems, the grounds for the changes and modifications which resulted in the systems as at present practised have not been sufficiently stressed, and a casual reader might regard the system as developing naturally rather than as being the result of efforts to meet special locality conditions and the requirements of the trees grown. It is fundamentally the particular requirements of the trees which lead to the elaboration of silvicultural systems, and as our knowledge of the factors governing tree growth and regeneration becomes fuller, so will systems be evolved which use that knowledge to secure improved results in practice. The criticism here made must not be taken as suggesting that this point of view has been omitted from the book, but only that it is insufficiently emphasized.

The order in the book is: System, points of the system, crops that can be grown on the system. The reverse order: Crop (species), requirements and peculiarities, systems under which the crop can be grown, is the way in which the problem will present itself in those parts of the Empire where little or no systematic work has yet been started.

The descriptions of the different systems are based on the author's personal knowledge of their working rather than on the literature dealing with them. The addition of lists of references to selected literature would have added to the value of the book, particularly references to the sources of the historical material.

The production of the book leaves nothing to be desired, and both the author and the publishers are to be congratulated on this addition to our forestry literature.

Zur Anatomie und Physiologie der Zuwachszonen- und Jahresringbildung in den Tropen. Ch. Coster. *Annales du Jardin Botanique de Buitenzorg*, 1927, 37 and 38.

(*The anatomy and physiology of the formation of growth zones and annual rings in the tropics.*)

A Note by B. J. Rendle

EARLY studies in botany, restricted as they were to plants growing under temperate conditions, led to the building up of a terminology which has sometimes suffered from a loss of exactitude when extended to tropical plants. The term 'annual ring', originally used in describing the structure of European trees, was later expanded to include the zones of growth discernible more or less clearly in the trunks of tropical trees. It was difficult to reconcile the presence of these growth zones with the prevalent idea, based on the scanty notes of travellers, that, in constantly humid tropical forests, growth is continuous throughout the year. The postulation of an inherent periodicity in the plant provided a feasible explanation, but was itself based on a comparatively weak foundation of recorded observations. When Schimper wrote his *Pflanzen-Geographie* in 1898 the periodic phenomena of tropical vegetation had not been studied in any detail. Since that time observations on the periodicity of leaf-change have been recorded in all parts of the world. The anatomical structure of growth rings has also been described, but the less easily investigated alternations in cambial activity in trees outside the temperate zone have remained to a large extent obscure. As recently as 1923 Jost wrote : 'Little is yet known about the formation of annual rings in tropical trees.'

The solution of the problem clearly lies in the continued observation, over a number of years, of the periodicity of leaf-change and cambial activity in a large number of species. It is not difficult to understand why such a laborious undertaking has not been carried out before. Most botanists stationed in the tropics are too fully occupied with their official duties to devote themselves to what is principally an academic question, while visitors from Europe usually stay at most a few months, too short a time for the magnitude of the task.

A notable contribution to our knowledge of this subject has been made by the author of the paper under review. His observations, extending over four years, were carried out in Java, a country peculiarly well suited to an investigation of this kind. Hardly any comparable area in the world has a flora of richer variety than Java. The climate, moreover, in spite of the relatively small size of the island, is by no means uniform throughout the area, a very slight degree of elevation above the sea-board plains producing a remarkable difference in temperature.

The investigations described were carried out in three separate localities. Toeban, in east Java, is in the monsoon region and possesses a well defined dry season from June to November. In west Java, including Buitenzorg with its famous botanic gardens, the rainfall is heavier and more equally distributed throughout the year, the annual precipitation, 170 inches, being about three times as much as in east Java. Dry periods of a few weeks sometimes occur and these have their effect on the ground flora, but deep-rooted trees and shrubs are not appreciably affected. The third region of observation was at Tjibodas, in the constantly humid and cool mountains of west Java, whose climate has been reckoned as the most uniform in the world.

After a brief review of previous work in the tropics the results of the author's own investigations are recorded, each species being described separately. The analysis of these observations, together with the results of experiments on the effect of defoliation,

ringing, &c., on the production of growth rings, forms the basis of a general discussion on periodicity and growth in thickness.

The number of tropical species studied was sixty-three. In addition, twenty-two species of introduced temperate zone trees were investigated. With a Pressler's increment borer a sample of wood and bark was removed from the trunk of each tree at various seasons of the year. Transverse sections of the cambium and young wood were cut and examined microscopically; twigs and small branches were examined in the same way. By this means the rise and fall of cambial activity were studied in relation to vegetative periodicity.

The alternation of leaf-fall and leaf-renewal presents an endless variety of appearance, each condition merging imperceptibly into the next. Not only is the behaviour of the various species dissimilar, but different examples of the same species vary according to conditions of growth and the age of the individual. The author first describes the normal process of leaf-renewal of tropical species growing in the periodically dry climate of east Java; then the influence of age and external conditions. Finally, the behaviour in the moist climate of Buitenzorg is compared with the normal growth-cycle in east Java. It will be interesting to give a brief summary of these observations before considering the relation of vegetative activity to growth in thickness.

The majority of trees in east Java normally shed their leaves in the dry season and stand bare for one to three months. The production of new leaves is generally delayed until the beginning of the rainy season, but in certain cases leaf-renewal habitually takes place before the end of the dry season, when the moisture content of the soil is at a minimum. A smaller group comprises those species which effect the complete change in a relatively short time ; the shedding of the old foliage is followed in a few days by the bursting of the new buds. This general change is usually made once a year during the dry season, but at least one species, *Terminalia Catappa* L., is recorded, which has a half-yearly periodicity and renews its foliage in the middle of the rainy season. In the third group, the evergreens, are included a number of species which form a link between the true evergreens and the deciduous trees. These intermediate forms cast a large proportion of their leaves during the dry season and show a general shoot development as soon as the rains begin. The true evergreens stand in full leaf year in and year out, sprouting more or less continuously all over the crown.

Examples are cited which serve to illustrate how natural periodicity is subject to the influence of age and environment. The youthful vigour of many trees is reflected in their longer seasonal growing period as compared with mature individuals. Saplings of typically deciduous species, for instance, commonly retain their foliage throughout the year. With the approach of maturity the annual resting period manifests itself, becoming gradually longer each year until it reaches the normal duration. Trees which have attained a great age exhibit a more strongly marked periodicity, and a similar effect is induced by unfavourable conditions of growth. For example, species which are normally evergreen or sub-evergreen tend to assume a deciduous habit if they are growing in poor, dry soil.

In the more uniform climate of Buitenzorg the general behaviour is much more irregular. The majority of trees pass through an annual resting period, but this may occur at different times for different individuals or even for different branches of the same individual. Some species, however, show no appreciable divergence from their normal behaviour in east Java. The evergreens naturally maintain their characteristic habit, while some species which are deciduous in east Java become practically evergreen under the more humid conditions of the Buitenzorg district. In the latter group there

are some which retain an annual periodicity in their separate branches, each of which becomes independent of the tree as a whole ('astweise autonom'). In others the length of the growing season is unchanged, but the resting period is reduced to a few days. *Toona serrata* Roem., for example, which is annually deciduous in a climate with a regularly recurring dry season, changes its leaves every eight months in Buitenzorg. Deciduous species which are more rigidly adapted to an annual resting period shed their foliage annually and stand bare for about three months, even though the conditions are favourable for normal vegetative activity. All possible intermediate conditions exist between the few types which have been mentioned. It is apparent that a species accustomed to an annual period of drought varies its response to a change in environment according to the strength of its inherent periodicity.

A close correlation exists between vegetative and cambial activity. In most of the trees examined the bursting of the buds is closely followed by a vigorous growth in thickness. The intensity of cambial activity diminishes when leaf-development is complete, but persists so long as the leaves continue to perform their living functions. So far as these investigations show, the cambium remains dormant while the tree is bare. The phenomenon, commonly reported in Europe, of initial growth in thickness preceding the bursting of the buds, was not observed in any of the species investigated. The author inclines to the view that the stimulus to cambial activity is provided by the developing organs of the tree. As a result of his experiments he concludes that the stimulus is probably transmitted through the medium of hormones formed in the leaves and transported to the cambium by way of the phloem.

A separate series of observations was carried out on a few introduced temperate trees. These were mostly investigated in the botanic garden at Tjibodas, 1,500 metres above sea-level, where seasonal variations are almost negligible. Here most of the broad-leaved species and all the conifers are in leaf throughout the year. But although the trees as a whole never stand bare, individual branches show an independent annual periodicity. It is not uncommon to see trees bearing branches in all stages of the vegetative condition, presenting a remarkable picture of the intermingling of the seasons. This phenomenon provides a striking illustration both of the persistence of inherent periodicity and of the independence of the different parts of a tree. It is perhaps scarcely justifiable to regard the behaviour of these few examples as typical of temperate species transplanted to the tropics, as most of the trees were immature and might not have settled down to a steady routine in their new environment.

The general conclusions which can be drawn from an investigation of this kind are not without practical significance. Much light is thrown on the vexed question of how far ring-counts can be used in determining the age of a tree. Actually, the rings themselves are often so irregular that an exact determination of age is practically impossible. The most that can be aimed at is a rough estimation. As a working hypothesis it may be conceded that a periodic interruption of vegetative activity generally results in the formation of corresponding growth zones in the trunk, though there are numerous exceptions to this rule. Consequently it is to be expected that trees which are known to pass through a regular annual cycle, as do the majority of species in east Java, will form true annual rings. But it is unsound to assume that the rings in all trees growing in a similar climate will correspond with annual periods. The case of *Terminalia Catappa* L., which sheds its leaves twice in every year, alternate changes being made in the middle of the rainy season, is certainly exceptional but probably not unique. The youthful evergreen habit of many deciduous species must also be taken into account. It is apparently unusual for vigorous tropical trees to form distinct growth

rings in the first few years of their life. Basal sections show an area in the middle of the trunk where growth rings are either poorly marked or altogether absent. The first distinct growth ring marks the beginning of the normal life-cycle of the species.

The presence or absence of growth rings in fossil wood has often been quoted as evidence of former climatic conditions. Seward in 1892 concluded that the knowledge of the cause of variation in cambium products was insufficient to justify any great reliance being placed on this particular feature. In the present state of our knowledge it can only be emphasized that single specimens are of little value in forming positive conceptions on the question of past climates. Only when a large number of species from the same geological formation show sharp, regular zones of growth, is the palaeobotanist justified in ascribing them to the effect of an annual period of physiological drought.

Holznahrung und Symbiose. Professor Paul Büchner, Breslau. Julius Springer, Berlin, 1928.

A note by R. Neil Chrystal

THIS paper is the published version of an address delivered at the tenth International Congress of Zoology held at Budapest in September 1927. It is a review of the progress up to date made in research on symbiosis, and a record of some recent studies by the author and his co-workers on the symbionts of wood-boring insects belonging chiefly to the orders Coleoptera, Hymenoptera, and Diptera.

In the introduction the author reviews the whole range of symbiosis throughout the animal kingdom and groups the different types of symbiosis into categories. The first of these is external symbiosis, and after considering the well-known examples of fungus culture by the leaf-cutting ant (*Atta*) and certain sub-families of the *Termitidae* (*Termites*), the author turns to the Coleoptera and deals with the scolytid 'Ambrosia' beetles. A short discussion on these, based on the findings of Schneider-Orelli and other workers, leads to an account of some new work on the Lymexylonid, *Hylecoetus dermestoides*, and its fungal symbiont. The occurrence of an ambrosia fungus in the tunnels of *Hylecoetus* has long been known, but the method of its transference has hitherto remained obscure. Buchner states that the fungus spores are carried by the females in special sac-like evaginations of the genital system which open into the vaginal canal, and the spores are smeared over the eggs as they are borne along and deposited in the wood. The larva on hatching consumes part of the egg-shell and with it the fungus spores, which are thus passed on from one generation to the next. The most remarkable addition to the ranks of the 'Ambrosia' fungus cultivators, however, is *Sirex*, in which definite evidence of symbiosis has been obtained. The fungus in question is a Basidiomycete, and was investigated in *S. gigas*. Here the oidia are contained in special pear-shaped glands lying at the base of the ovipositor. They pass into the oviposition tunnel with the eggs, the fungal hyphae subsequently infecting the wood tissue in the immediate vicinity of the tunnel. This is considered to be a new type of ambrosia culture, because in this instance the fungus is not the food of the insect, but provides it by rendering the wood substance digestible by means of an enzyme.

Internal symbiosis is then dealt with and Cleveland's work on the flagellate symbionts of Termites considered in detail. Büchner states that these micro-organisms are not mere commensals whose only function is to keep the food in constant motion, but that they break down complex food material.

A discussion of symbiosis between bacteria and coleopterous and dipterous species

follows, the latter being represented among others by certain tipulid wood-boring larvae. The conditions are closely similar in all cases, both adults and larvae possessing what the author calls 'ferment chambers', which are sac-like appendages of the gut into which they open. These chambers are filled with bacteria.

Three Lamellicorn beetles, *Potesia*, *Oryctes*, and *Sinodendron*, are dealt with, and the symbiosis of *P. cuprea*, the rose beetle, is described in some detail. The larvae of this beetle live among the decaying wood and needle refuse of ant-hills, and carry their bacterial symbionts in sacs attached to the hind-gut. Some definite evidence relating to the work of these bacteria is produced. Thus it has been shown by Werner that only in the winter, when feeding ceases, do the ferment chambers remain full of wood particles untouched by the bacteria. Again, a bacillus capable of dissolving cellulose has been isolated in pure culture from these chambers. It has been found that the optimum temperature for bacterial activity (33–7° C.) corresponds closely to the optimum for larval growth. Once the temperature of the ant-hill falls below 21° C., which takes place towards the end of October, there is a complete cessation of activity on the part of the host and symbiont.

In close relationship to the 'ferment chambers' of the Lamellicorn larvae is the 'yeast symbiosis' ('Hefesymbiose') of the Anobiidae. Of these, *Sitodrepa panicea* is selected as a type, and here the Saccharomycetes live in large sacs attached to the mid-gut in the larva, and in special appendages of the female reproductive organs for the purposes of transference. Again, we find the eggs smeared over with the spores in a similar fashion to that described in *Hylecoetus*, the young larvae consuming the greater part of the egg-shell after hatching. This Saccharomycete type of symbiosis was also found in a large range of Longhorn wood-borers, and the pages dealing with the recent work on these are among the most remarkable in the whole paper. Here we find a similar larval and adult mechanism for the use and carriage of the symbionts respectively. No fewer than seven sub-groups of the Cerambycidae are cited as 'sichere Symbiontenträger', and this number will doubtless be greatly extended in the future. Still pursuing his search for further examples of symbiotic phenomena among the wood-feeding Coleoptera the author turns to the Curculionidae, which provide examples of bacterial symbiosis in *Hylobius*, *Pissodes*, *Cryptorrhynchus*, *Cleonus*, *Otiorrhynchus*, and other genera. Here again the general features of their occurrence are closely similar to those of the Cerambycidae. To complete the picture the Buprestid larvae were also drawn upon to provide evidence of bacterial symbiosis, which is discussed in the case of two larval forms, one unknown, and the other that of *Catoxantha* (*Megaloxantha*) *bicolor*, a large tropical Buprestid.

One general principle, stressed by the author in relation to all the above-mentioned examples of bacterial symbiosis, is worthy of note, namely that in the larval stage the bacterial chambers are so placed as to be in communication with that part of the gut where the bacteria act upon the food contents; but in the adults the chambers are in connexion with the reproductive system, and are reservoirs for the storage of bacterial spores which are handed on to the next generation. The adult food being mostly liquid, the bacterial symbiosis is not a necessity for them.

Towards the end of the paper the author, reverting once more to the Diptera, discusses Petri's work, published some twenty years ago, on the bacterial symbionts of *Dacus oleae*, Rossi, the well-known Olive fly of South Europe. He is of the opinion that a rich field of discovery awaits the investigator into other leaf-mining and gall-making Trypetidae, and also suggests that the Cecidomyid gall makers of the genus *Asphondylia* and others are likely bearers of symbionts.

Such are the main facts dealt with in this work, and it is evident that a wide field has been opened up for the study of the biological interrelationship between these micro-organisms and their hosts. Ample proofs of the presence of these organisms in the insect orders dealt with are given, and the mechanism of transport is also partly known. Further work is necessary on the lines indicated above, and it is likely to be fruitful in the more important wood-boring insects such as the Lyctidae and Anobiidae.

Beetles Injurious to Timber. J. W. Munro. *Forestry Commission Bull.*, No. 9. London: H.M. Stationery Office, 1928. Price 1*s.* 3*d.*

A Review by J. G. Myers

WHEN the cultivator finds his crops endangered by insect attack or the farmer discovers a heavy infestation of lice or ticks on his stock he may, according to his temperament, regard it as an act of God or blame the weather; but he realizes in most cases that any effectual measures to prevent or lessen the damage must be taken by himself and usually by himself alone. In the older countries the agriculturist has largely depended on his own traditional methods; in recently settled lands the novelty and the magnitude of the problem have left him dependent on government advice, and have led to the development of applied entomology.

But the insects are no specialized predators on the primary producer alone. Practically all goods of organic origin are subject to insect attack from their earliest stages of elaboration to their final stages of consumption. The passage from producer to consumer may be lengthy and involved. When insect damage becomes patent at any point in the journey, whose is the blame and whose shall be the loss? The holder of the goods at this stage is no longer in the position of the man on the land—he can lay the blame on previous links in the human chain, and he usually does so. Stored products entomology has thus been largely nobody's task, and has become the very Cinderella of entomological science.

The insects which attack stored products, including timber, are often almost cosmopolitan forms, species which have been so widely spread by commerce that their geographical origin is no longer apparent. This renders their identification usually a simple matter, but the ensuing task a more difficult one than in the case of an agricultural pest. Only the minutest study of the life-history and ecology of the insect under all conditions will decide when, in the commercial process, infestation occurs and how it may be prevented.

No one realizes more strongly than Dr. Munro the need for such data where timber insects are concerned; and few have contributed so much towards supplying it under British conditions. The bulletin under review is a concise but very readable account of the chief beetles injurious to timber in England. There is a short introduction which we could wish had been longer, followed by sections on the four main groups of timber-boring beetles—the longicorns, the pin-hole borers, the powder-post beetles, and the furniture beetles—which together constitute, next to the termites of warmer lands, the most redoubtable enemies of this increasingly important material.

Each of these four sections begins with a very brief account of the structure and appearance of members of the group, considers their life-history and pre-adult stages, remarks on a few representative species, discusses the timbers attacked and the damage done, and concludes with suggestions for preventive and remedial measures.

'The longicorn beetles and pin-hole borers are essentially forest insects, for they

attack timber just after it has been felled and abandon it when it has become dried or seasoned. The powder-post and furniture beetles, on the other hand, are enemies of seasoned timber, the former abounding in timber-yards and the latter infesting antique furniture and the roofs of old buildings.'

One is impressed by the number of species of beetles which have found their way into this country in imported timber. It is pointed out that most of the longicorns (Cerambycidae) prefer unseasoned timber as a breeding-ground, and are thus not likely to become established unless the timber-yards are in forest districts. Nevertheless, at least three species of longicorns have become established in this way.

The great interest of the pin-hole borers (Scolytidae and Platypodidae) lies in their feeding upon a fungus which they grow upon the walls of their tunnels. This interest has been accentuated by Büchner's [1] sensational discovery that symbiotic relations with special fungi are of very much wider occurrence among wood-boring insects in general—a discovery which should throw light on many unsolved problems in the nutrition of these insects.

Whether or not a certain timber is attacked by beetles may depend upon factors which would never be guessed without a detailed knowledge of the life-history and habits of the insects concerned. Thus it appears that the immunity of birch, beech, maple, and true mahogany from the attacks of the powder-post beetles (*Lyctus*) must be attributed not to extra hardness nor to any specially deterrent properties, but merely to the small size of the pores; for these beetles '*show considerable acumen* in selecting suitable pores or vessels in the sapwood in which to lay their eggs' (reviewer's italics). It must be confessed we like this statement. On pragmatical grounds it is probably far wiser for the applied entomologist to credit insects with acumen than to attribute to them nothing but forced movements or tropisms.

The control of timber beetles presents in an exaggerated form a difficulty which meets the entomologist in many fields—a difficulty which concerns human nature rather than science. The tremendous sale of patent medicines bears witness to the conflict which still rages between the sham and the scientific medical practitioner. In entomology above all, the demand for a panacea or a miraculous cure is usually apparent in implicit or explicit form the moment the expert appears on the scene. He is too often expected to suggest some single, simple, even if expensive, method of direct extermination. A recommendation to go and wash in Jordan is still met, if not with indignation, at least too often with disappointment. The entomologist who, in the light of a thorough biological knowledge of a timber pest, sees in slow turn-over, accumulation of stocks, and untidy yards a predisposing condition for infestation, and who therefore suggests moderate changes here and there in every-day practice, may even be regarded as encroaching on matters which do not concern him. Yet the applied scientist must and should, to an ever-increasing extent, enter into all phases of the particular industry in which the insects he is studying constitute a pest. Thus, and thus only, will efficient, economical, and permanent control be achieved.

In dealing with longicorn beetles and pin-hole borers especially, Dr. Munro has stressed such methods of prevention. In the case of the former pests he states that, by felling at the right time (when the beetles are not flying), by early removal of the timber from the forest, by rapid handling and conversion, 'losses can be reduced to a minimum or even wholly avoided'.

Steam-kiln seasoning for dealing with powder-post beetles is described, and insecticides for furniture beetles are formulated. As a non-staining and unobjectionable liquid

[1] Buchner's *Holznahrung-Symbiose* is reviewed on page 130.

for valuable woodwork, the late Professor Lefroy's mixture of orthodichlorbenzene, cedar-wood oil, and Castile soap is recommended.

The whole bulletin is well and clearly written, save a sentence on p. 24 where the larva (of *Anobium*) is said to gnaw a hole in the wall of the pupal chamber to simplify the work of the beetle 'after pupation'. This surely means '*after emergence* from the pupa'.

The plates are from well-selected photographs of damaged wood, while the text-figures are charming, original pen-and-ink drawings of the more important beetles, the life-like position of whose legs seems to indicate an enviable independence of the usual insect-draughtsman's expedients for reproducing bilateral symmetry.

It is earnestly to be hoped that in the near future the author will find time to write, with the same happy combination of systematic, ecological, and practical data, a comprehensive manual of forest entomology for Great Britain.

Mycorrhiza, by M. C. Rayner, D.Sc. Wheldon & Wesley Ltd. London, 1927. (New Phytologist reprint.) Price 21*s*.

A Review by W. R. Day

THE appearance of a general book of reference on mycorrhiza is a matter of importance, for until the present time there has been no work which has dealt adequately with this important and interesting subject. In forestry a mild interest has always been taken in mycorrhiza; but it is only within recent years that there has been any real awakening to the fact that until the biology of the soil and of the relationship of the forest to the soil is understood the economy of the forest can never be truly appreciated, the conditions necessary for the full health of the trees realized, and the maximum profit obtained from the crop. Recent years have seen notable advances in the study of mycorrhiza, and advances which are of great importance to the forester in particular. Nevertheless, little or none of this work could be referred to in English, and the great importance of Dr. Rayner's book is that it gives a full and complete account of the whole subject, which by its publication becomes open not merely to the research student, but to those engaged in administrative and executive duties, and who have little or no time for the detailed study of a numerous and scattered literature.

An excellent feature of the book is that it deals with the subject historically, so that a clear review is obtained of the development of observation and research during the hundred years in which it has been known that fungi are, in certain cases, associated with the root system of the higher plants. The subject is dealt with in three periods. The *early period* covers the years 1840–80 and is concerned with the observations and speculations of those who first began to realize that mycorrhiza existed. The end of this period is marked by the pronouncement of the theory of symbiosis by De Bary. The *second period*, 1880–90, is distinguished from the first by the much more accurate conception of what the association of fungus and root really is. During the first half of this second period Kamienski and Frank recognized mycorrhiza as a morphological entity. The theory of beneficial symbiosis between the mycorrhizal constituents was propounded, and Frank divided mycorrhiza into ecto- and endotrophic types. The second half of the period saw the further development of this theory. It became recognized that 'humus plants' existed which by the aid of mycorrhiza drew their food to a greater or less extent from the organic remains constituting humus. The cytology of intercellular digestions was worked out, and the way prepared for the third and *modern period*, 1900–25.

The greater part of the book is occupied with this period, which is marked by partly successful attempts to determine experimentally what exactly is the relationship between the fungus and its host. Thus the function of mycorrhiza in the Ochidaceae and the Ericaceae has now become much clearer. It is known that the host plant definitely benefits from the association with the fungus, and that under natural conditions this association must exist if the host is to develop. The work of Melin on the mycorrhiza of certain conifers has also made it clear that they certainly benefit by the association, and from this it is practically certain that all other trees which develop mycorrhiza also benefit. It is not yet fully determined exactly what the benefits obtained are, but undoubtedly they are all due to the ability of the fungus readily to assimilate complex organic substances of which the host itself could use but little if any. One of the principal benefits is that a supply of nitrogen becomes available to the host, either by nitrogen fixation, as in the case of the Ericaceae, or by assimilation from humus, as with the mycorrhiza of trees.

Apart from what has been already mentioned, the mycorrhiza of Bryophyta is fully dealt with and also the association of tuberisation with fungal infection. In a concluding chapter the physiological significance of mycorrhiza is discussed and a general review and summary given of the evidence regarding its function in the Ochidaceae, Ericaceae, and in the mycorrhiza of trees.

It is impossible in a short review to do full justice to a book containing a mass of so detailed information as does this. It suffices to say that it is an indispensable work to any who take up the study of this most interesting subject. The book is well produced, with clear illustrations. An index is provided and a bibliography of the very extensive literature mentioned. The author is to be congratulated on having produced a most useful and necessary work, and one moreover which is not merely useful but also attractive. It may be commended to all foresters as providing that general knowledge without which it is impossible to understand even partly one very important side of forest biology.

Manual of Forest Engineering and Extraction. J. F. Stewart. London: Chapman & Hall, 1927. Price 15*s*.

A Review by F. A. Leete

THE author states in the preface that the book is primarily intended to serve as a simple text-book for university forestry students.

My chief criticism of the book is that it does not go sufficiently into practical details for the general reader. Each of the chapters might serve as the basis for a series of lectures on any one subject, but, without access to other and more detailed information, it would be impossible for any one on his own to carry through anything but pioneer work.

Except as regards some of the statements in the last chapter on Forest Extraction in India, I have nothing but praise for the quality of the information given. The author must have had wide experience, and he handles the various subjects in an interesting manner. But that is as far as I can go. There is nothing like as much detail as there ought to be in my opinion. But even if the chapters had not been considerably expanded by more detailed discussion, the practical value of the book could have been greatly enhanced by the addition of an extra page or two containing a list of titles, publishers, and prices of more advanced text-books and papers, to which any one desirous of going more deeply into any particular subject might refer.

In India little or no pioneer work (in the sense used by the author) remains to be

done. It is rather a matter of developing the work done by several generations of foresters, many of whom proved themselves to be sound practical engineers.

In respect to India, I do not subscribe to the view that work on more or less permanent roads, bridges, and buildings is ordinarily beyond the scope of the forest engineer, and that for any big job the services of the Public Works Department would be available. My experience was that such work had to be done by the ordinary forest officer (before forest engineers were even thought of), or else it was not done at all. More or less everywhere progress in development was directly proportional to the taste for and active interest in engineering problems on the part of individual forest officers. It is much the same to-day. Even though there are some forest engineers in India and Burma, there are not many of them. It would be fatal to progress if it were to be assumed that there is any less need to-day than there was in my time for the ordinary forest officer to take the initiative in, and therefore to have a good working knowledge of, the engineering problems likely to arise in the development of intensive extraction. I do not know much about present-day arrangements for the training of foresters in engineering, but I hope that they are much better than they were when I was a student at college.

Before I left Burma a number of tractors had been purchased by various timber firms. Hardly a single one of them was a success at first, chiefly because most people had very vague ideas as to what the machines could really do and as to how they ought to be handled. In more than one instance the mistake was made of thinking that purchase was everything, and that a mechanic on the pay of an elephant driver was fit to be trusted with such a complicated piece of mechanism in an out-of-the-way place and at a considerable distance from engineering workshops and stores, such as exist in Rangoon but hardly anywhere else in the country. A simple breakdown often meant the machine being laid up for days or weeks at a time. The four pages on tractors might very well have been doubled without going beyond what a practical man should know, but very frequently does not know, when called up to run or advise upon a tractor proposition.

Estimates of capital cost, output under varying conditions, and running expenses are amongst the first things a man looks for when thinking about backing a project for a tractor, skidding machine, or forest railway. The author gives him no help at all with regard to any of these important details. Is the problem in mind big enough and will it stand the expense? It is true that prices of materials and labour vary enormously, but any average figure taken as the basis for detailed estimates would serve the purpose. It would be a simple matter to modify them to suit any particular proposition.

Chapter XIII deals with sawmills and seasoning in eight pages. The value of a book intended to be of use to students going to all parts of the world would have been greatly enhanced if an attempt had been made to describe and compare sawmill practice in the principal countries. It is not far wrong to state that there is one and only one standard type of log mill in the North American Continent. It is only in details that differences occur. What a contrast is presented in Great Britain and in Europe generally! Hardly two mills alike anywhere. Coming down to details the question might well be asked, Why is the plain rack bench still so common in England, although there are probably none to be seen outside museums in Canada and the U.S.A.? Bandsaws furnish another example of very marked difference in practice. In England horizontal bandsaws are frequently to be met with, but on the other side of the Atlantic vertical bandsaws are everywhere preferred.

The author ventures the opinion that the elephant will soon be replaced by the

tractor for logging in India (he should have said Burma). I doubt it. Teak logging is very scattered, owing to the fact that there are not more than one or two trees to be handled per acre. It is true that the elephant is less powerful and works more slowly than the tractor, but he is remarkably mobile, he can feed himself in the forests, and he is not so liable to sudden breakdowns. For hauling from stump he is therefore likely to be able to hold his own for a long time to come. The chance for the tractor lies in the next stage, i.e. for the transport of numbers of logs for good distances along the same track.

The Protection of Woodlands. G. W. St. Clair Thompson. London: H. F. and G. Witherby, 1928. Price 10*s.* 6*d.*

A Review by R. N. Chrystal

THE appearance of this handbook on forest protection of British woodlands is a welcome addition to British forestry literature, and should do much to stimulate the interest of foresters in this increasingly important branch of forestry. The main thesis of the book, that good silviculture is the ideal of forestry, and that control measures against pests should, whenever possible, be sought for along natural lines, is thoroughly sound, and the plan of the book is well adapted to bring out the force of this argument. The author in his opening chapter discusses the main principles of forestry, and deals at some length on the respective merits of pure and mixed woods. The statements he makes regarding the relationship between the plantation and its enemies are well worth the serious consideration of practical foresters. In Chapters II and III the author deals with the birds and animals of the forest, and his synoptic arrangement of the species enhances the value of the book as a reference work. Writing of the great spotted woodpecker, *Dendrocopus major*, the author states on p. 68 that this bird is the only effective natural agent in the control of *Siricidae*. Having had to consider this question recently, I have found no evidence, based on stomach analysis, that there is any support for this view, which has already been advanced by Evans and others.

The final chapter is devoted to a general discussion on practical forest protection, beginning with the silvicultural aspect of the subject and following on with the various forms of biological and artificial control. The passage on p. 161, in which the author wholeheartedly condemns the practice of biological control measures by insect parasites, seems a little premature, inasmuch as no concerted effort has so far been made in this country in this direction. Surely some tentative experiments might be started, although the author does well to warn his readers against over-confidence regarding the results.

On the entomological side one or two criticisms are called for. The nomenclature which the author has adopted in the Chermesidae leaves something to be desired. For instance, he speaks of *Chermes corticalis*, which is a synonym for the well-known *Pineus strobi*, and *C. abietis-laricis*, which may be *Cnaphalodes strobilobius* or *C. abietis*, depending on the circumstances. Strangely enough, dealing with the same family, the author makes no mention of the Dreyfusia species on the silver fir, which are by far the most important Chermes in this country, inasmuch as they are such serious pests in young plantations. As regards other insect pests discussed by the author, one would hardly include such species as *Agrilus viridis*, an excessively rare beetle in this country, and *Lymantria monacha*, one of the more costly items to be found in dealers' catalogues, as British forest pests of any serious moment.

The book is slightly marred by a number of misprints of scientific names. These have been noticed on pp. 40, 49, 51 (here *Syrphidae* has been listed under *Hymenoptera*), 59, 72, 106, 155, 156, 162, 193, and in the index.